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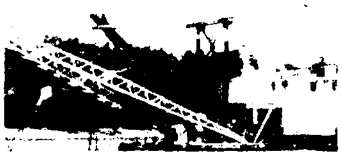

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TECHNICAL REPORT D-89-1

LONG-TERM MONITORING OF ELEVEN CORPS OF ENGINEERS HABITAT DEVELOPMENT FIELD SITES BUILT OF DREDGED MATERIAL, 1974-1987

by

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Eleven habitat development field sites built by the US Army Corps of Engineers (CE) on dredged material were monitored from 1974-1987 in response to questions regarding their ecological contribution and longevity in comparison to natural habitats. Seven of these sites (Nott Island, Connecticut; Windmill Point, Virginia; Buttermilk Sound, Georgia; Apalachicola Bay, Florida; Bolivar Peninsula, Texas; Salt Pond #3, California; and Miller Sands Island, Oregon) were built during the CE Dredged Material Research Program. Four sites (Gaillard Island, Alabama; Lake of the Woods, Minnesota; Pointe Mouillee, Michigan; and Southwest Pass, Louisiana) were built by CE Districts and added to the long-term monitoring effort at the request of Mobile, St. Paul, Detroit, and New Orleans Districts.

Each of the 11 sites differed according to the type of habitat developed, location, dredged material substrate, structural development, water and energy regime, land-use

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one appears in the Proceedings of the Beach Technology '88 conference. Coastal Zone '89 was held under the auspices of the American Society of Civil Engineers, and Beach Technology '88 was held under the auspices of the Florida Shore and Beach Preservation Association. In support of the Coastal Zone '89 conference, the editor of this report organized a special session of five of the papers included here under the session theme, "Shoreline Change and Storm-Induced Beach Erosion Modeling," also used as the title of this report.

This information is expected to be of interest to US Army Corps of Engineers field offices and other public and private organizations involved with technical aspects of beach change modeling and the use of models in project planning and design.

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SUMMARY

The long-term study and monitoring of 11 habitat development field sites built by the US Army Corps of Engineers (CE) on dredged material in various locations throughout the United States were accomplished initially through the Dredged Material Research Program (DMRP), 1973-1978, which was conducted at the US Army Engineer Waterways Experiment Station (WES). At that time, seven field sites were built and developed in cooperation with CE District offices. From 1979 through 1987, under the Environmental Effects of Dredging Programs, Dredging Operations Technical Support, four additional field sites built by Districts with technical advice and assistance from WES were included in the long-term monitoring effort.

In response to questions regarding the ecological contribution and longevity of the original seven field sites, a decision was made to undertake a long-term monitoring effort and to select reference sites at each of the field sites for comparison. Four new sites were added because they were each different from the original seven. Each of these 11 sites were chosen because each differed according to habitat developed, location, dredged material substrate, structural development, water and energy regime, land use potential, regional habitat needs, salinity, or other pertinent features that were representative of those encountered most often by field personnel in CE District offices where dredging occurs. Nine are intertidal, ~~five~~ are in fresh water, ~~three~~ in brackish water, and three in salt water. One is located in the Great Lakes and another on the US-Canadian border. Two are large-scale, ongoing confined disposal facilities (CDF).

Study objectives were to (a) document the long-term stability of each site, (b) determine successional changes taking place, (c) relate site functions and values to natural systems, and (d) demonstrate that habitat development could be accomplished using dredged material. Since 1974, 39 WES technical reports and more than 100 technical papers have been published documenting site progress and presenting data analyses on the 11 sites.

A summary chapter on each field site is presented in this report, and each is very briefly discussed in the following paragraphs. Two levels of monitoring were conducted: an intensive level in which vegetation, soils, benthic, and fisheries data were collected and a low-level effort in which vegetation, wildlife, and environmental and physical changes were documented

at each site visit. Monitoring varied slightly between sites, depending upon availability of personnel and site requirements.

Gaillard Island CDF was built in 1980-1981 by the Mobile CE District. Located in lower Mobile Bay at the junction of the Mobile Ship Channel and the Theodore Barge Channel, this CDF is 3.2 km from shore and is a triangular-shaped, 525-ha diked island with a 250- to 300-ha shallow containment pond. The CDF replaced the bay bottom with a combination of island, wetland, and upland habitats and has provided diverse habitats that include gently sloping dikes, vegetated swales and borrow pits used for feeding and nesting, shallow-water feeding areas, intertidal and brackish marshes, and extensive nesting areas in varying stages of vegetation development.

The isolated location and the habitat diversity provided by the CDF have allowed it to be used by nesting waterbirds since its construction. For example, terns, gulls, and skimmers were nesting before the dikes were actually completed in 1981. Nesting has greatly increased each year, and in 1987, over 20,000 seabirds nested there, including seven tern species, laughing gulls, brown pelicans, black skimmers, black-necked stilts, willets, and American oystercatchers. Vegetation is currently reaching the stage to encourage tree/shrub nesting species such as herons and egrets, and cattle egrets began nesting in 1987. In summer months, over 1,600 brown pelicans and over 750 American white pelicans have been observed on the CDF. Since 1983, brown pelicans have been nesting on the island, and in 1987 the species had 331 successful nests. The largest black skimmer colony on the northern gulf coast is located here (over 2,000 nests), and more than 700 least tern nests were also observed in 1987.

Gaillard Island has provided an important testing site for wetland development studies using biostabilization techniques and has contributed highly significant waterbird nesting habitats. The island is also providing a long-term, managed containment site for large quantities of dredged material from Theodore Channel and for US Navy Homeporting. Continued wildlife and fish use of the CDF is concurrent with dredging and disposal operations.

Pointe Mouillee is a 1,862-ha site that encompasses a 365-ha CDF, over 400 ha of shallow water/emergent marsh habitat, and over 1,000 ha of wetland meadow, forest, and fields that are part of the Pointe Mouillee State Game Area. The site is located on the western shore of Lake Erie, where severe shoreline and wetland erosion had greatly impacted the game area.

Well-armored with riprap, the CDF was completed in 1983 and built on the site of and in the configuration of an old eroded barrier island and has provided protection for the entire site. Natural resource features incorporated into the joint CDF/game area long-term management plan drafted in 1979 include extensive wildlife and fisheries management; fishing piers; a visitors' center; marina; hiking, biking, and jogging trails; waterfowl and small game hunting; and numerous year-round events such as fishing rodeos and decoy-carving contests.

Wetland and upland habitat restoration since the CDF construction has been dramatic. A total of 145 bird species use the site, including numerous nesting species, a heronry, and two colonies of gulls and terns. It is a major stopover for thousands of migrating shorebirds and waterfowl each year. The four-cell CDF is being filled over a period of years, and in two compartments nearly filled, both upland and wetland habitats have formed, including shallow ponds fringed with cattail and bulrush and used by local fishermen. The natural marsh behind the CDF is slowly recovering, and sedimentation from reduced water flows provided by culverts through access dikes is helping the emergent freshwater marsh to increase. The CDF has found wide acceptance by local citizens who use the site frequently.

Lake of the Woods, an unconfined disposal island placed in 1983 at the mouth of Warroad Harbor in lake of the Woods, Minnesota, on the US-Canadian border, is the newest and smallest (2 ha) of the field sites. For much of its existence, it has been underwater because of record lake levels occurring soon after it was built; however, water levels have recently been receding. The site colonized with cattail and softstem bulrush, and a mud flat that originally formed on one side of the island is now a dense bed of aquatic plants extensively used by waterfowl. Lake currents changed the island from round to kidney-shaped in only 1 year, but the island has become relatively stable in this configuration as an emergent marsh/aquatic plant bed. Terns, cormorants, herons, egrets, and waterfowl species are the primary users. This site will continue to be monitored for change after 1988 by the St. Paul District and Minnesota Department of Natural Resources.

Southwest Pass is the large area south of Head of Passes, Louisiana, where the primary Mississippi River Ship Channel is located. Erosion and subsidence are taking an estimated 142 sq km each year from the Louisiana marshland. Since 1970, the New Orleans District has been pumping unconfined dredged material into shallow water areas to form large areas naturally colonized by intertidal marsh species. This action has resulted in the formation of over 2,000 ha of new marsh, with some high marsh/shrub habitat creation that will gradually subside to also become intertidal marsh. Within the small study area selected at Southwest Pass, 883 ha of intertidal land has been created since 1970, but 173 ha of it has been lost to subsidence in the same period. A net gain of 408 ha of marsh has resulted, with 302 ha of mud flat still unvegetated but rapidly being colonized with emergent vegetation. The New Orleans District will continue to use this dredged material placement method for marsh development, with a projected 14,164 ha to be developed with existing dredged material from current projects.

The Nott Island field site was begun in 1974 and is a 3.2-ha upland meadow located on a 31-ha island in the Connecticut River near Old Lyme, CT. An old sandy dredged material deposit was temporarily diked, filled with silty dredged material, then disked, and mixed. The prepared site was then limed, fertilized, and planted with a seed mixture of legumes and grasses. The site has remained vegetated throughout the study and appears to be quite stable, with the meadow slowly resembling a typical New England old-field plant and animal community. By contrast, three reference areas, while stable, are still bare or nearly unvegetated sand mounds.

The Windmill Point field site, also begun in 1974, is an 8-ha dredged material island in the James River downriver from Hopewell, VA. A temporary sand dike was placed, then filled with silty dredged material. The site naturally colonized into a dense cover of arrow arum, pickerelweed, and arrowhead plants within one growing season. Physically, the site remained relatively stable for 9 years, then began eroding away after the dike was compromised during river floods in 1983. It currently consists of two smaller islands connected by an expanse of shallow water habitat and mud flat. Much of the marsh has been washed out, but the site is still productive from a benthic-, fish-, and wildlife-use standpoint because of its location and its habitat diversity. The three reference areas have all remained stable.

The Buttermilk Sound field site is a 3-ha sandy dredged material island in the Altamaha River near Brunswick, GA, and was developed in 1974. The island was an old deposit of sandy dredged material that had not vegetated; this deposit was shaved down to an intertidal elevation, planted with a number of low and high marsh species, and monitored. Over time, smooth cordgrass, big cordgrass, and saltmeadow cordgrass dominated at different elevations, and the site is now virtually stable. It is also much more attractive to area wildlife because of the habitat diversity the island provides, and more than twice as many bird and mammal species use this site than the three reference areas. Benthic data were also collected, and abundance was similar to reference areas.

The 5-ha Apalachicola Bay field site, located on a dredged material island built near Apalachicola, FL, was developed in 1976. A weir was installed in the dike surrounding the containment island, silty dredged material was pumped inside, and the site was planted with smooth cordgrass and saltmeadow cordgrass. Over time, the intertidal area has become densely vegetated with smooth cordgrass, while the high marsh has mixtures of saltmeadow cordgrass, saltgrass, and other species. The weir stopped functioning, but two breaches in the remaining dike serve to provide intertidal flow. The upland portion of the island was planted with trees and grasses, and the entire complex has been heavily used by wildlife.

The Bolivar Peninsula field site was developed in 1974 and consists of the original field site and two adjacent deposits of sandy dredged material, as well as a change in study at the original site to include impact of marsh smothering and recovery. Located in Galveston Bay, Texas, the sandy mound on Goat Island was fenced, temporarily diked with sandbags, shaved down to an intertidal level, and planted with a variety of upland species, smooth cordgrass, and saltmeadow cordgrass. Over time, the intertidal area consists solely of smooth cordgrass, while the planted upland grasses and trees have been crowded out by saltmeadow cordgrass and other invading plant species. On the two new areas, one to the west of the old site was planted using erosion control matting, floating and fixed-tire breakwaters, and other biostabilization techniques in 1984 and 1985. It is becoming vegetated with smooth cordgrass, and both sites are being compared with the deposit on the east of the old site, which was not planted and serves as a control. In the smothering study begun in 1986, high marsh is replacing the smooth cordgrass that was covered, and the site appears to be too high to recolonize with smooth cordgrass. The old field site was compared with the three reference areas and found to be less in plant biomass but with range of variability, and more productive from a wildlife standpoint. Benthos and fisheries use of the old site were equal to or greater than reference areas.

The Salt Pond #3 field site is located in an abandoned salt pond in south San Francisco Bay, California, and was begun in 1972. The pond was filled with silty dredged material; then the dike was permanently breached and a tidal channel dug to allow intertidal exchange. The lower portion of the 40.4-ha site was planted with Pacific cordgrass, Pacific glasswort, and pickleweed. Over time, the cordgrass has spread to become totally vegetated in the lower one-third of the site, while the glasswort and pickleweed have spread to cover the remainder of the salt pond, including those portions that were not planted. Prior to dredged material placement and planting, the pond had not revegetated even when intertidal flow had been allowed prior to 1974. Wildlife use of the site was very similar to the three reference areas, and plant composition and cover were within the range of variability at the end of the study. Benthos data were also similar.

The Miller Sands field site is a large dredged material island built in 1932 in the lower Columbia River in the Lewis and Clark National Wildlife Refuge. Beginning in 1974, wetland, upland meadow, and dune habitats were planted and developed. Over time, the dune habitat has been tremendously successful, the wetland habitat has gone from a dense vegetation cover over the entire planted area to about half that size as the result of washing from a chute that eroded through the island sand spit, and the upland meadow has changed from a lush cover of grasses and legumes to a much less productive but stable meadow dominated by scour rush, with lesser stands of tall fescue and other grasses. Benthos, fisheries, and wildlife use were all equal to or better than three reference areas, although percent cover and biomass of vegetation was less.

These 11 field sites provided a wealth of technical information regarding habitat development, especially wetlands. The CE field offices and others who require techniques, methodologies, approaches, and step-by-step guidance and information necessary for wetland and island development should find this 14-year study to be of great value, whether the habitat is being built from dredged material or for other reasons, such as for Section 404 mitigation or compensation for habitat losses.

Ten major recommendations for habitat development and restoration using dredged material and other construction soils include:

_a_. Carefully plan projects where habitat development will be included, even if the dredging work has already taken place and the habitat development is to be on an existing site.

_b_. Examine nearby sites in the project vicinity to determine habitat needs and the likelihood of construction success.

_c_. As with any biological or agricultural project, be sure to take into account site variables, and allow some margin of error.

_d_. Develop a set of criteria and objectives where habitat development and natural resource goals are included during project early planning stages.

_e_. Remain flexible in these criteria and objectives, because a site may develop over time into a similar but equal habitat rather than the hoped-for habitat because of unforeseen factors.

_f_. Develop a contingency management plan in case alternate habitats should evolve over time on the dredged material.

_g_. Provide careful instruction to dredging inspectors whose responsibilities include seeing that elevational and dredge pipe movement specifications are exactly fulfilled, and follow up on projects to be sure that they are completed as specified.

_h_. Provide funding as well as authorization for habitat development activities that accompany District operations and maintenance dredging work.

_i_. Monitor habitat development projects to determine success or failure and to document construction and site development activities.

_j_. Develop long-range management plans for dredging and placement that incorporates natural resource beneficial uses.

In addition to the above, numerous recommendations discussed in EM 1110-2-5026 and Technical Report DS-78-16 are also pertinent. These two documents include such recommendations as species for certain types of habitats and soils, propagation and planting methods, engineering design and construction of sites, estimating costs, and other site-specific considerations.

PREFACE

This report presents the results of long-term habitat development monitoring of 11 dredged material placement sites. Seven sites were built as part of the Dredged Material Research Program (DMRP), and four were built by US Army Corps of Engineer (CE) Districts. All have been monitored under the auspices of the DMRP and the Environmental Effects of Dredging Programs (EEDP), Dredging Operations Technical Support (DOTS), assigned to the US Army Engineer Waterways Experiment Station (WES), Environmental Laboratory (EL), Vicksburg, MS. The programs were funded by the Headquarters, US Army Corps of Engineers (HQUSACE), Washington, DC. Mr. David B. Mathis was the HQUSACE Technical Monitor.

The study encompasses 14 years of long-term data from these 11 representative sites. Authors of this technical report are Dr. Mary C. Landin, Dr. James W. Webb, and Mr. Paul L. Knutson, Wetlands and Terrestrial Habitat Group (WTHG), Environmental Resources Division (ERD), EL. Dr. Landin was the Principal Investigator. Work progressed under the general supervision of Mr. Hollis H. Allen, Team Leader, Habitat Resources Team; Dr. Hanley K. Smith, Chief, WTHG; Dr. Conrad J. Kirby, Jr., Chief, ERD; and Dr. John Harrison, Chief, EL. Dr. Robert M. Engler was Manager, EEDP, and Mr. Thomas [illegible]. Patin was the EEDP DOTS Coordinator.

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COL Dwayne G. Lee, EN, was the previous Commander and Director of WES. COL Larry B. Fulton, EN, is the present Commander and Director. Dr. Robert W. Whalin is Technical Director.

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PART I: INTRODUCTION

Background

1. The long-term study and monitoring of 11 habitat development field sites built by the US Army Corps of Engineers (CE) on dredged material in various locations throughout the United States (Figure 1) were accomplished initially through the Dredged Material Research Program (DMRP) that was conducted at the US Army Engineer Waterways Experiment Station (WES) from 1974 through 1978. At that time, seven field sites were built and developed in cooperation with CE District offices. From 1979 through 1987, under the Environmental Effects of Dredging Programs, Dredging Operations Technical Support (DOTS), four additional field sites that had been built by Districts with technical advice and assistance from WES were included in the long-term monitoring effort.

2. These 11 field sites were chosen for study and long-term monitoring because each was uniquely different according to type of habitat developed, field site location, type of dredged material substrate, structural development, water and energy regime, land use potential, regional habitat needs, salinity, or other pertinent features that were representative of those encountered most often by field personnel in CE District offices where dredging occurs. The field sites are widely representative of conditions found in US waterways. Nine are intertidal, five are in fresh water, three are in brackish water, and three in salt water. One is located in the Great Lakes (Lake Erie), and another is located on the US-Canadian border. Two are large-scale, ongoing confined disposal facilities (CDF). A list of the 11 sites and a brief tabulation of their characteristics are given in Table 1.

3. The major objectives of long-term monitoring of CE field sites were (a) to document their long-term stability, (b) to determine successional changes taking place, (c) to relate their value and function to natural systems, and (d) to demonstrate that habitat development could be accomplished using dredged material, even under ongoing placement conditions. The seven

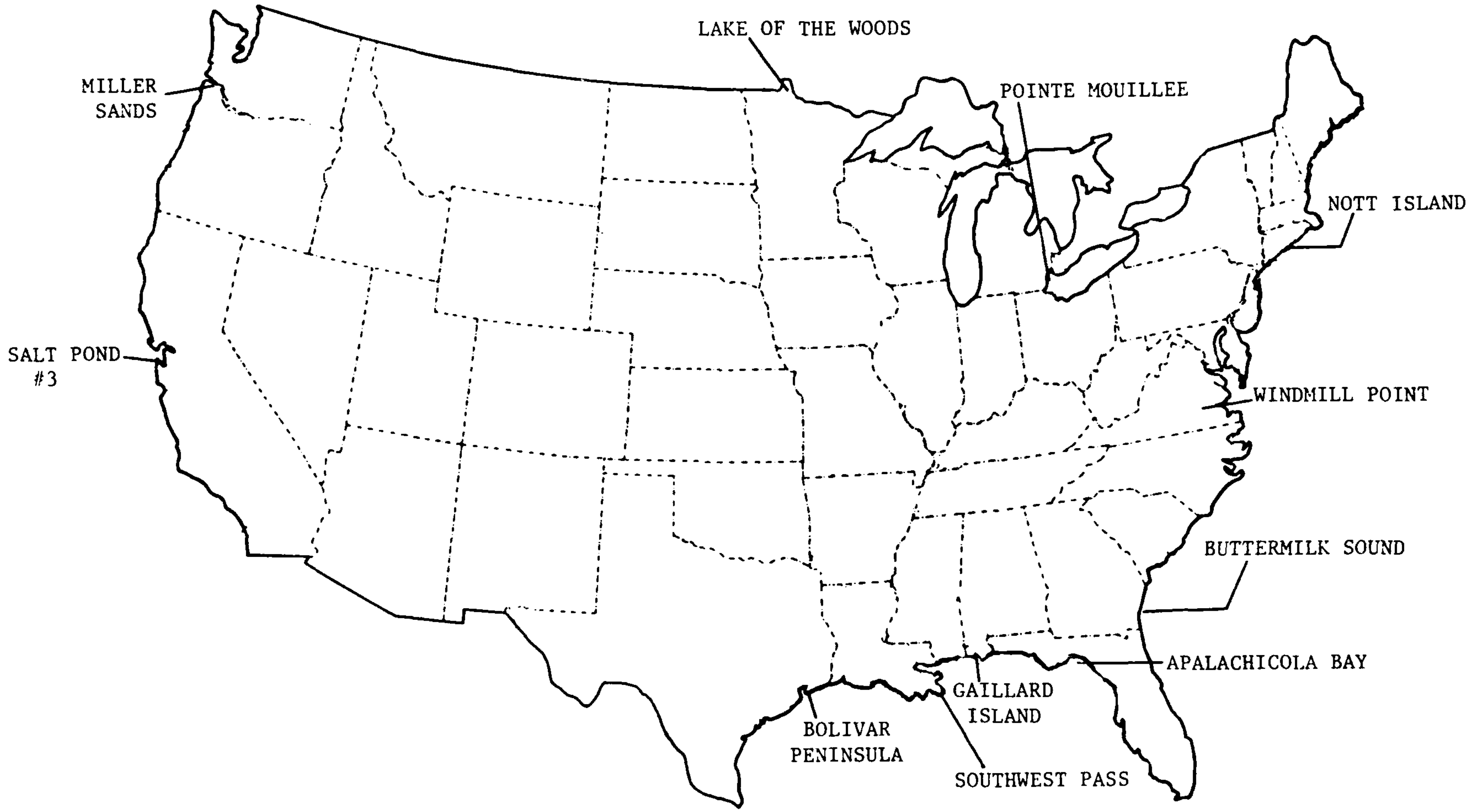

Figure 1. The 11 CE habitat development field sites that were monitored in the long-term study

Table 1

Corps Habitat Development Field Sites in the Long-Term Monitoring Effort

Site Location	Water Source	Salinity	Dredged Material	Habitat and Development and Remarks
Gaillard Island, Mobile Bay, Alabama (intertidal)	Estuary	Brackish	Silty sand	Multipurpose
Pointe Mouillee, Lake Erie, Michigan	Lake	Fresh	Silty sand	Multipurpose
Lake of the Woods, Warroad, Minnesota	Lake	Fresh	Silty sand	Wetland and island
Southwest Pass, Miss. River, Louisiana (intertidal)	River	Brackish	Silty sand	Wetland
Nott Island, Conn. River Connecticut (intertidal)	River	Fresh	Silt/ sand	Upland meadow
Windmill Point, James River, Virginia (intertidal)	River	Fresh	Silt	Wetland and island
Buttermilk Sound, Altamaha River, Georgia (intertidal)	Estuary	Brackish	Sand	Wetland and island
Apalachicola Bay, Apalachicola, Florida (intertidal)	Estuary	Saline	Silt	Wetland and island
Bolivar Peninsula, Galveston Bay, Texas (intertidal)	Estuary	Saline	Sand	Wetland and upland
Salt Pond #3, San Francisco Bay, California (intertidal)	Estuary	Saline	Silt	Wetland
Miller Sands Island, Columbia River, Oregon (intertidal)	River	Fresh	Sand	Multipurpose

original field sites built during the DMRP also were compared with nearby natural habitats with similar characteristics (Newling and Landin 1985).

Study and Monitoring Methodology

4. Two levels of monitoring effort were developed for all sites. The first level included an annual general reconnaissance of all sites, conducted by WES personnel. General reconnaissance was intended to provide qualitative information on changes that might require closer scrutiny (massive erosion, plant mortality, unexpected land use change) and to note functions and values of the habitats.

5. The second level of monitoring was intensive sampling and was planned to provide quantitative data from the five sites that had received the greatest amount of research effort during the DMRP (Windmill Point, Buttermilk Sound, Bolivar Peninsula, Salt Pond #3, and Miller Sands Island). Intensive sampling was conducted at least once at each of these five sites between 1978 and 1981 and included plant and soil sampling at all wetland sites and benthos and sediment sampling at Windmill Point, Bolivar Peninsula, and Miller Sands. This work was conducted both inhouse at WES and under contract to professional consultants. From 1982 through 1987, a general reconnaissance of all 11 sites was made annually and usually involved low-level quantitative vegetation sampling along established permanent transects through each field site to determine vegetation successional changes. On all site visits, wildlife and fish, plant colonization or change, and physical changes were recorded.

6. Plant and soil sampling was conducted in randomly selected 0.5-sq m quadrats along established transects through field sites. Nondestructive sampling parameters recorded were species occurrence, stem density, stem height, number of flowering stems, percent cover, and general vigor and health of the vegetation. Aboveground biomass destructive sampling included harvest of all vegetation in each quadrat, clipped at soil level at low tide. Belowground biomass destructive sampling involved taking a 10-cm-diam core to a depth of 25 cm from each quadrat, divided into 5-cm increments. Soils were analyzed for various physical and chemical parameters, depending upon the field site, but usually included particle-size analysis, volatile solids, percent

moisture, bulk density, pH, total Kjeldahl nitrogen, total phosphorus, and total organic carbon.

7. Benthic macroinvertebrates were sampled and analyzed at Miller Sands, Bolivar Peninsula, and Windmill Point. At each sampling station, sediment samples were analyzed for grain size and volatile solids. In addition, rate of predation on macroinvertebrates was determined by caging studies at Bolivar Peninsula and Windmill Point.

8. At the four newer field sites, every effort was made to use methods consistent with that used on the seven older sites within the constraints of budget and manpower. Vegetation, soils, wildlife, and physical and environmental changes were documented on these four sites using identical methods from the older sites. The exception was that no destructive sampling was conducted, and vegetation parameters were stem height, stem density, percent cover, number of flowering stems, species occurrence, and general vigor and health. No benthic or fisheries quantitative data were collected, and no natural reference sites were selected for comparisons. Again, this was also due to budget and manpower constraints.

9. For additional documentation over time on the status of the 11 field sites, ground-level photographs from fixed and random points were taken at every site visit throughout the 14 years of study. Aerial photographs have also been taken on an infrequent schedule as changes appeared to warrant this level of effort.

Documentation

10. Extensive early-phase (1974-1978) documentation on the seven older sites has been published in 39 WES technical reports, permanently available through the National Technical Information Service (NTIS), Springfield, VA, and more than 100 technical papers. Midphase (1979-1982) data were published in Newling and Landin (1985), also available through NTIS. Data for the four newer sites and 1983-1987 data from the seven older sites have been partially published in technical journals and conferences. Appendix B is a bibliography listing uncited publications relevant to these 11 sites.

PART II: GAILLARD ISLAND, LOWER MOBILE BAY, ALABAMA

Background

11. Gaillard Island (GI), built in 1980-1981 in lower Mobile Bay by the . .bile District, is an excellent example of the CE effort to incorporate the beneficial uses of dredged material in a CDF while accomplishing the CE mission of maintaining navigation channels. The GI CDF was built to provide a placement site for dredged material from the deepening and widening of Theodore Ship Channel and its maintenance material (Landin 1986a). It originally had a projected 50- to 80-year life; however, since the US Navy now uses the CDF for placement of material connected with the Navy Homeporting Program, GI will fill faster than anticipated.

12. The habitat development being accomplished as a part of this project represents CE habitat development in conjunction with a fully active coastal/estuarine CDF. In addition to demonstrating that wetland development could be used to stabilize dikes under moderate wave-energy conditions, the CE objectives have been to show that it could manage for avian wildlife under normal operating conditions and to enhance seabird nesting potential using placement of material from maintenance dredging activities.

13. Long-term monitoring and wetland development tests were conducted from 1981-1987 by WES. Additional bird count data have been provided to the District by local birding groups who are interested in the island's development as wildlife habitat. The District is beginning an agreement with the Alabama Department of Natural Resources to continue limited bird-nesting monitoring activities, although collection of vegetation and nonnesting wildlife data will not continue. No quantitative data for benthos or fisheries have been collected since the island was built, although observational data and interviews with commercial and sports fishermen have been recorded. Data from the GI site have been presented in Allen, Webb, and Shirley (1983, 1984, 1986); Webb, Allen, and Shirley (1984); Landin (1986a); Allen (1988); and Landin and Miller (1988).

Site Development

14. The triangular-shaped, 525-ha GI site was built at the junction of Theodore Barge Channel with Mobile Ship Channel, 3.2 km from the western shoreline of Mobile Bay (Figures 2 and 3). A secondary channel is located on the third side of the island. The island was constructed with silty sand dredged material hydraulically pumped using a suspension boom. Using this placement method, broad, gently sloped dikes were formed surrounding a large, interior containment pond with approximately 250 to 300 ha of shallow water. Gaillard Island replaced bay bottom habitat with a combination of island, wetland, and aquatic habitats.

15. Project plans for GI began in the 1970s and culminated with island construction. A long-term management strategy for the CDF is being developed by Mobile District. It has input from a permanent interagency working group and incorporates both engineering and environmental features. It also emphasizes coordinated working conditions that will expand the working life of the island while continuing to provide valuable wildlife and fish habitat (US Army Engineer District (USAED), Mobile 1988).

16. The three dikes are maintained and upgraded using dredged material either from maintenance dredging or borrowed from the island's interior. Construction of the CDF in an area with some soft foundation created a challenge for the District and has been met using a variety of means. Threatened by subsidence on portions of the south dike and overtopping by three hurricanes, dike integrity has been restored by using dredged material pumped into some minor breaches and by borrowing from existing dewatered material in the CDF. Erosion from wind fetch and ship waves has also caused some dike stabilization problems; therefore, the east dike (Mobile Ship Channel side) has been armored with riprap. Stabilization on the northwest dike (secondary channel side) has been provided by planting smooth cordgrass and on the south dike (Theodore Channel side) by a combination of planting smooth cordgrass and armoring with riprap.

17. In 1982, Mobile District installed a large temporary ungated weir on the northern end of the east dike to allow for intertidal exchange with the containment pond. This was done to relieve pressure on the dikes from an accumulation of rain water and water from the dredging process. The District

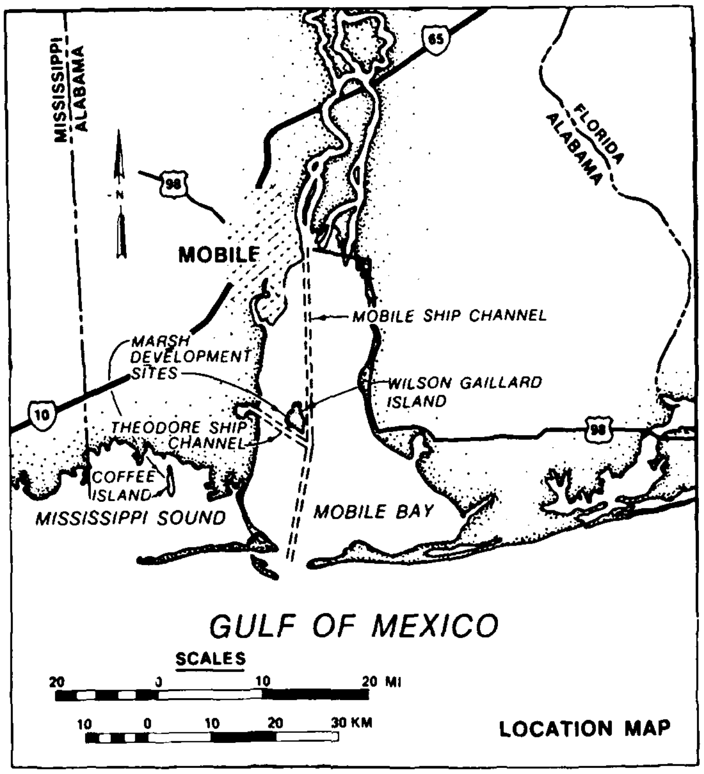

Figure 2. Gaillard Island at the junction of Mobile Ship and Theodore Barge Channels in Mobile Bay, Alabama

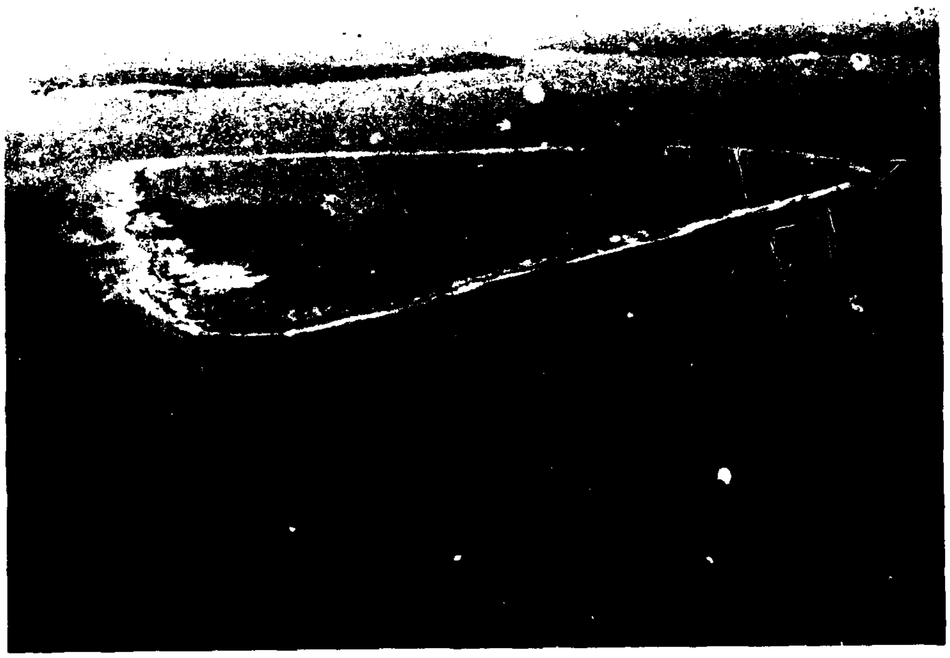

Figure 3. Gaillard Island CDF in 1985, with the east dike adjacent to the Mobile Ship Channel in the foreground

plans to install permanent weirs on the northwest dike as the island fills with dredged material.

18. Environmental data collection of GI has been limited in scope because of funding and manpower restraints. However, vegetation and wildlife colonization has been documented both qualitatively and quantitatively as much as possible using the same low-level monitoring approach taken for older WES field sites. Wildlife and vegetation colonization data since the construction of the island are provided in the following sections.

Wildlife and fish

19. Seabirds. Even before construction of GI was completed, seabirds were congregating and nesting on the dikes. From 1984 through 1986, an estimated 16,000 birds nested on the island each year. In 1987, this number increased dramatically to over 20,000 nesting birds, and by 1988, over 30,000 birds were nesting there (this report does not include 1988 GI data except for an occasional reference to these data provided by personal communication with Mr. Douglas Nester, Biologist, Mobile District). These huge populations of nesting birds are not an unusual phenomenon for dredged material islands, and such rapid colonization and large populations have occurred on dredged material placement sites in North Carolina, Mississippi, Louisiana, Texas, Florida, the Great Lakes, Chesapeake Bay, the Columbia River, and other areas (Landin 1980, 1984, and 1986b).

20. Table 2 lists nesting species on GI, the year in which nesting first occurred, and nesting estimates for each year. Schematics of the three dikes of GI, showing colony locations for 1986 and 1987, are shown in Figure 4. Nest counts were made each year using one of two methods. In colonies where numbers of nests were low or where the data on the species were considered critical (endangered or rare), every nest was counted. In colonies with very large numbers, a 10-m-wide belt transect in which every nest was counted was walked through the colony. An estimate of number of nests was then determined by measuring the size of the colony area and extrapolating. Numbers of eggs and chicks in each counted nest were noted, and averages for eggs/chicks per nest were determined.

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* Common and scientific names mentioned in the text are listed in alphabetical order by common name in Appendix A.

Table 2

Nesting Species on Gaillard Island CDF

Species	Number of Nests 1981	1982	1983	1984	1985	1986	1987
American oystercatcher	--	--	--	--	--	1	1
Black-necked stilt	--	1	2	4	7	11	25
Black skimmer	500*	800*	1,200*	1,575*	1,500*	1,750*	2,000*
Boat-tailed grackle	--	--	--	1	1	1	2
Brown pelican	--	--	1	8	133	224	331
Caspian tern	--	--	50*	50*	75*	63	115*
Clapper rail	--	--	1	1	2	2	2
Common grackle	--	--	--	--	1	4	9
Common tern	--	--	--	--	--	7	10
Forster's tern	--	--	6	12	13	9	25*
Gull-billed tern	--	--	--	20	35	42	47
Herring gull	--	--	--	--	--	--	3
Laughing gull	1,500*	3,000*	4,500*	6,000*	6,250*	5,500*	6,000*
Least tern	22	14	19	27	40	194	700*
Marsh wren	--	--	1	2	2	3	3
Red-winged blackbird	--	--	--	1	3	9	10
Royal tern	23	35*	40*	50*	63	74	90*
Sandwich tern	--	1	1	3	1	2	4
Seaside sparrow	--	--	1	1	2	2	4
Snowy plover	--	--	--	--	--	4	3
Willet	--	1	1	1	1	1	2
Nest Totals	2,045*	3,852*	5,823*	7,756*	8,129*	7,912*	9,386*

* Nest numbers were estimated in larger colonies.

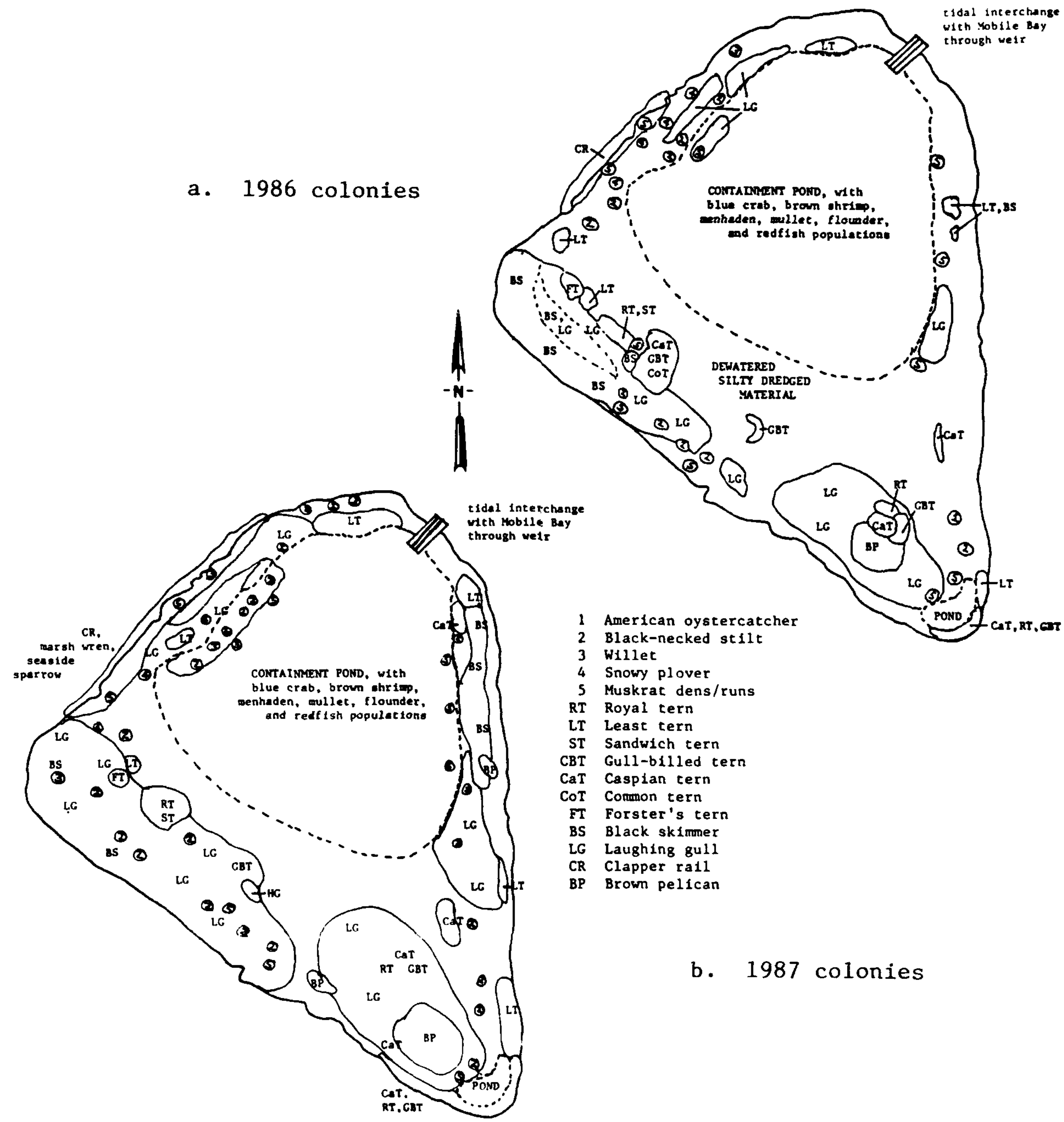

Figure 4. Nesting colonies on GI

21. Colony data were recorded early in the morning to prevent disturbance to the nesting birds in the heat of the day. No attempt to record data for dates of egg-laying and incubation, for chick survival, or for fledging rates was made. An intensive monitoring effort would have been necessary to accomplish this and would have resulted in undue nest disturbance from frequent colony intrusions.

22. In 1981, an estimated 4,000 laughing gulls, black skimmers, and terns were nesting. An estimated 7,000 birds of the same species nested in 1982 and have nested in increasing numbers each year (Table 2). Black skimmers increased in 1986 and 1987, respectively, to an estimated 1,750 (over 3,800 individuals observed) and 2,000 nests (over 4,800 individuals observed). This is the largest black skimmer colony on the northern gulf coast, and the birds have been averaging 2.8 eggs/nest. Some black skimmers also nested on the inside of the containment area on well-drained and dewatered silty sand. However, the largest skimmer concentrations were on the outer south dike slopes (Figure 5).

23. Over 12,000 laughing gulls nested on GI in 1985. This number dropped slightly in 1986 due to construction activities on the east dike. However, an increase in both numbers of other seabird species and individuals within other species was noted. Since gulls are predators on tern eggs and chicks, the temporary decrease in gull nesting was considered a benefit to other species. In 1987, laughing gull populations returned to above 1985 levels and could be stabilizing at about 12,000 to 15,000 nesting birds. However, laughing gull colonies on smaller dredged material islands in Tampa Bay sometimes have more than 30,000 nesting birds, and the GI population could continue its expansion (Soots and Landin 1978).

24. Seven species of terns (least, Caspian, royal, common, Forster's, gull-billed, and Sandwich) were nesting on GI by 1986. There were 194 least tern nests in 1986, which was a great increase for this species over previous years. However, in 1987, over 700 least tern nests were observed in numerous small colonies at GI, which represented an almost fourfold increase in nesting for that species. As bare ground habitat becomes available, least tern nesting is expected to continue to increase. Least terns were averaging 1.9 eggs/nest in 1987.

25. Under current and planned conditions at GI, there are abundant tern, skimmer, and gull habitats available for nesting. Caspian, royal,

Figure 5. Black skimmer colony on GI, the largest in the northern gulf coast region

Sandwich, gull-billed, and least terns nest on bare or nearly bare areas on the island dikes, while common, gull-billed, and royal terns and black skimmers nest in sparse herbaceous vegetation cover. Forster's terns and laughing gulls nest in dense herbaceous cover, especially on the island's south dike and portions of the northwest dike. These required successional stages of vegetation that are so suitable for the nesting populations at GI should continue as long as GI remains an active disposal site and should follow guidelines for nesting requirements in Soots and Landin (1978).

26. Some gull-billed, royal, and Caspian terns nested on the fine-textured silty dredged material inside the dewatered portion of the containment area where desiccation cracks in the drying dredged material were less distinct. Chicks clambered in and out of these shallow cracks as they moved about the colonies with no apparent injury. Gull-billed terns collected small oyster shell fragments for their nests and laid two to four eggs on these small mounds.

27. Pelicans. Within a year of island construction, both brown and American white pelicans were using the containment pond for loafing and feeding. Nonbreeding American white pelicans have remained on GI year-round, but have not yet attempted to nest. These birds are subadult individuals from

the large flocks that nest on 14 to 15 islands in reservoirs and lakes of the western and midwestern United States and migrate south each winter. White pelican numbers have varied each year from an estimated 400 to 500 in 1984 and 1985 to a high of 763 in 1987.

28. In 1983, brown pelicans built four nests on the east dike of GI. One nest was successful, and two chicks fledged. This range expansion brought back nesting brown pelicans into Alabama for the first time in this century. In 1984, eight nests were successful, and in 1985, 133 nests fledged over 250 chicks. This remarkable increase in colony size was further enhanced by over 200 nests in 1986 in which over 500 chicks fledged (Figure 6). In 1987, brown pelicans were nesting at three different locations on the south and east dikes, and 331 nests fledged approximately 700 chicks. A 1987 summer population of over 1,600 adult (nesting) and subadult brown pelicans was observed on GI.

29. When brown pelicans began nesting on GI, they were still listed on both the Federal and State of Alabama endangered species lists. The US Fish and Wildlife Service (FWS) has downgraded brown pelican endangered status on the Atlantic and gulf coasts. In 1985, based largely on the one colony in Alabama (on GI), the State of Alabama also removed the brown pelican from its

Figure 6. Brown pelican colony on GI in 1986, located on the south dike near the junction of the two main ship channels

endangered species list. Since this is the only brown pelican nesting colony between south Florida and south Louisiana, these delistings may be premature.

30. Other bird species. By summer of 1982, herons, egrets, and other water-related species had discovered suitable feeding areas inside GI. These feeding areas consisted of four habitats: (a) the ponded, brackish swales on the outer dike faces created as a result of subsidence and sand accretion; (b) the shallow water of the large containment pond; (c) the borrow pits created on the inside of the dikes from dike upgrading; and (d) the planted intertidal marsh on the outer face of the northwest dike.

31. Heron and egret species observed using GI habitats through 1987 included great blue heron, little blue heron, tri-colored heron, yellow-crowned night-heron, great egret, snowy egret, and cattle egret. Until late August 1987, no nesting by these species occurred. During August-September of 1987, a small colony of cattle egrets nested late on the south dike where the most dense vegetation and largest of the planted trees were located. Mobile District has since reported that these egrets returned and nested again in 1988 at the same location.* As vegetation on GI becomes more suitable for tree/shrub-nesting species, nesting will increase.

32. Other waterbirds frequently observed on GI include nesting black-necked stilts and clapper rails. Black-necked stilts have steadily increased their nesting use of the island as vegetation and habitat have become available. Stilts have been observed nesting almost exclusively around the vegetated brackish swales and borrow pits. By 1986, 11 pairs were nesting, and in the summer of 1987, an estimated 25 pairs were nesting, with as many as 78 stilts in 1 day's sampling sighted in these two habitats. Clapper rails have been found only in the planted saltmarsh on the northwest dike. Nests of clapper rails are very difficult to locate, and no more than two rail nests in any one nesting season have been located (Table 2); more rails could have been present.

33. Shorebirds have used GI habitats during migration and for overwintering since the CDF was under construction. During spring and fall migrations, thousands of these birds could be observed feeding on mud flats inside the containment area and along the shoreline. In addition to this heavy

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* Personal Communication, 1988, Mr. Douglas Nester, Biologist, USAED, Mobile, Mobile, AL.

feeding use, willets, American oystercatchers, and snowy plovers nested on the island (Table 2).

34. Waterfowl also used the containment pond on GI for feeding and resting, with considerable overwintering use by lesser scaup, ruddy ducks, and other diving species, and mallards and American black ducks. Mottled ducks nest on dredged material islands and in natural marshes along the northern gulf coast. A pair of mottled ducks were observed on the island in the summer of 1987; however, no nest was located.

35. Only a few perching birds (songbirds) were observed on GI through 1987. This is largely due to the CDF being located 3.2 km offshore. However, nesting has occurred by marsh wrens and seaside sparrows in the planted marsh. In addition, common grackles, boat-tailed grackles, and red-winged blackbirds have nested in vine thickets and small trees on the higher areas of the dikes, especially the south dike. Barn swallows and other swallow species have been observed each year feeding over the containment pond during migration. Barn swallows, bank swallows, and purple martins also fed over the island during summer months and undoubtedly were nesting on the mainland and flying over to feed at GI. Table 3 lists all bird species that have been observed on GI from all sources through 1987.

36. Muskrats. In 1985, muskrats colonized GI. Although their source of origin is unknown, it is believed that they floated on logs and driftwood from the rivers feeding Mobile Bay or possibly could have swum the 3.2 km from shoreline marshes. Enough muskrats were on GI by mid-1986 to populate all vegetated areas on the three dikes. Runs and dens on the dikes, and around the swales and borrow pits, were common. In 1986, one muskrat mound was found in a south dike swale; however, all other dens appeared to have been located in the dike banks. Since muskrats feed almost exclusively on vegetation, especially on saltmarsh bulrush and American three-square, they have not presented a threat to the nesting seabirds on GI.

37. Other wildlife. Two other incidental species have been found on the island. In 1985, an alligator was found in the containment pond. By 1986, the alligator had been shot by recreationalists using GI. In 1987, two alligators about 1.0 to 1.5 m long were found in the containment pond. These alligators probably came from rivers feeding Mobile Bay or from the shoreline marshes. Since Mobile Bay is at times nearly fresh water and seldom exceeds

Table 3

List of Wildlife Species Observed on GI, 1981-1987

Species	Year First Observed	Largest Number Observed/ Estimated	Habitats and Remarks
		Birds	
American avocet	1984	2	On mud flats, migrating
American black duck	1983	25*	In pond, overwintering
American coot	1983	16	In pond, overwintering
American oystercatcher	1986	2	Nesting in short grass on NW dike
American white pelican	1982	763	In pond, year-round
Bank swallow	1982	500**	Feeding over pond, late summer and fall
Barn swallow	1982	25**	Summer, over pond
Black-bellied plover	1985	25**	On mud flats, migrating
Black-necked stilt	1982	78*	Nesting at brackish swales and pits
Black rail	1986	1	Darting into saltmarsh
Black skimmer	1981	4,844*	Nesting, S and E dikes
Black tern	1984	1	On dike shoreline
Blue-winged teal	1983	4	In pond, migrating
Boat-tailed grackle	1984	4	Nesting in shrubs/vines
Boneparte's gull	1985	3	On dike, overwintering
Brown pelican	1981	1,600**	Nesting, 4 locations on S and E dikes
Caspian tern	1982	400**	Nesting, S and E dikes
Cattle egret	1986	30**	Nesting, S dike
Clapper rail	1983	5	Nesting, NW dike
Common crow	1987	3	On dike, migrating
Common grackle	1985	15	Nesting on S dike
Common loon	1983	3	In pond, overwintering
Common tern	1985	26	Nesting, S dike
Double-crested cormorant	1982	15	In pond, overwintering
Dunlin	1984	500**	On mud flats, migrating
Fish crow	1986	6	Feeding at shoreline
Forster's tern	1983	25**	Nesting, S dike
Gadwall	1982	4	In pond, overwintering
Great blue heron	1981	10	Feeding in pond
Great egret	1981	3	Feeding in pond
Greater yellowlegs	1981	19	On mud flat, migrating
Gull-billed tern	1983	47	Nesting, S dike

(Continued)

* Estimates of individuals.
** Actual population on GI exceeded this number.

(Sheet 1 of 3)

Table 3 (Continued)

Species	Year First Observed	Largest Number Observed/ Estimated	Habitats and Remarks
Herring gull	1981	100**	On shoreline, winter
Horned grebe	1983	1	In pond, overwintering
Knot	1981	50**	On shoreline, migrating
Laughing gull	1981	15,000*	Nesting on all 3 dikes
Least sandpiper	1981	100**	On shoreline, migrating
Least tern	1981	1,800**	Nesting on all 3 dikes
Lesser yellowlegs	1983	4	On mud flat, migrating
Lesser scaup	1983	1,000*	In pond, overwintering
Little blue heron	1982	3	Feeding in swales
Long-billed dowitcher	1982	75*	Shoreline, migrating
Mallard	1983	100*	In pond, overwintering
Marbled godwit	1984	21	On mud flats, migrating
Marsh wren	1983	5	Nesting in saltmarsh
Mottled duck	1986	2	Swimming in borrow pit
Mourning dove	1986	6	Feeding on dike crest
Northern shoveler	1985	4	In pond, overwintering
Osprey	1987	1	Over pond, wintering
Pectoral sandpiper	1984	10	On mud flats, migrating
Pied-billed grebe	1982	3	In pond, overwintering
Piping plover	1984	6	Shoreline, migrating
Red-breasted merganser	1983	1	In pond, overwintering
Redhead	1983	3	In pond, overwintering
Red-winged blackbird	1984	19	Nesting in shrub/trees
Ring-billed gull	1981	75**	Shoreline, wintering
Royal tern	1981	250**	Nesting, S and E dikes
Ruddy duck	1983	15*	In pond, overwintering
Ruddy turnstone	1984	500**	On mud flat, migrating
Sanderling	1982	100**	On mud flat, migrating
Sandpipers, unid.	1981	50**	Shoreline and mud flat, migrating, wintering
Sandwich tern	1982	7	Nesting, S dike
Seaside sparrow	1983	30**	Nesting, high marsh
Semipalmated plover	1982	5	Shoreline, migrating
Semipalmated sandpiper	1981	25**	On mud flats, migrating
Sharp-tailed sparrow	1983	8	In marsh vegetation
Short-billed dowitcher	1982	100**	On mud flats, migrating
Snowy egret	1983	50**	Feeding in swales, pond, borrow pits
Snowy plover	1985	7	Nesting, NW dike crest
Solitary sandpiper	1982	2	Inside dike shoreline, overwintering

(Continued)

* Estimates of individuals.
** Actual population on GI exceeded this number.

(Sheet 2 of 3)

Table 3 (Concluded)

Species	Year First Observed	Largest Number Observed/ Estimated	Habitats and Remarks
Sooty tern	1986	4	On shoreline, autumn
Spotted sandpiper	1984	1	On mud flats, wintering
Tri-colored heron	1983	4	Feeding in marshes
Upland sandpiper	1984	16	Inside dike shoreline, overwintering
Western sandpiper	1982	300**	Shoreline, migrating
Whimbrel	1984	3	On mud flat, migrating
White ibis	1987	13	Shoreline, migrating
Willet	1982	14	Nesting, NW and S dike
Yellow-crowned night-heron	1983	11	Feeding in marsh
	Other Animals		
American alligator	1985	2	In pond, year-round
Gopher tortoise	1987	1	On E dike crest
Muskrat	1985	7	All dikes, year-round

* Estimates of individuals.
** Actual population on GI exceeded this number.

(Sheet 3 of 3)

20 ppt salt around GI, alligators could tolerate that much salt water for a short period of time in reaching the island.

38. The other incidental species found on GI was one gopher tortoise found in 1987 on the crest of the east dike. This animal, a member of an endangered species, could not have reached the island except by accidental rafting or by deliberate placement and was completely out of its typical habitat of coastal longleaf pine forest. Photographs were taken of the animal, but it has not been sighted since that time.

Aquatic biota

39. The low level of monitoring at GI did not include quantitative data collection on aquatic biota. Observations of abundant feeding in the containment pond by fish-eating birds such as pelicans and other seabirds and the increase in nesting and successful fledging were taken as general indications that a relatively large community of aquatic organisms was living inside the containment area. Reports and interviews with commercial and sport fishermen, crabbers, and shrimpers also gave strong indications of large populations of blue crabs, brown shrimp, and flounders in the pond, especially near the weir on the east dike. In 1985, one group of commercial crabbers reported daily catches of 120 to 200 lb of blue crabs from the containment pond and said they had been crabbing inside the dikes for 3 years. Catches of mullet, menhaden, and redfish have also been reported, and amateur crabbers and handnet shrimpers boated out and frequented the shallow waters of the pond.

40. One of the most obvious indicators of fish populations in the containment pond was the hundreds of American white pelicans and brown pelicans that fished in the pond. Throughout the day on a year-round basis, white pelicans fed there, and they were joined by the large brown pelican population from April to October.

Vegetation

41. The first vegetation appeared on GI within months after the dikes were built, with the occurrence of a few species such as dog fennel, the nesting substrate used by brown pelicans 2 years later. Since 1981, natural colonization steadily increased, but due to its insular location has not matched the pace of a typical disturbed soil or disposal site located closer to or on the mainland. Soil salinity and compaction and the nonavailability of natural propagules may have slowed colonization in early months. However, high precipitation in the Mobile area, coupled with moderately well-drained

silty sand dredged material over parts of the dikes, allowed fresh and brackish plant species to colonize and grow over time.

42. Table 4 shows plant species occurring on GI and notes whether the species was seeded, planted, or invaded naturally; the year in which it first appeared on the island; and the habitat in which it grew. Large portions of the three dikes, especially the south and northwest dikes, were nearly completely covered over with dense herbaceous vegetation by 1985. In general, plant colonization on the crests of the dikes have been greatly affected by dike upgrading, which set the area upgraded back to an unvegetated condition. Soil texture and porosity were also factors. Sideslopes of dikes generally colonized before, or established from aerial seedings, the crests of dikes or shorelines. Plant species colonizing the island benefited from artificial plant establishment areas because these areas provided protection and rooting substrate for naturally occurring seeds and other propagules.

43. Planted wetland areas. From 1981 through 1986, WES conducted a series of dike stabilization experiments involving moderate wave energies on GI, in which smooth cordgrass was planted in the intertidal zone on the northwest dike and portions of the south dike (Allen, Webb, and Shirley 1983, 1984, 1986). These plantings were coupled with low-cost erosion control features to provide temporary protection to the planted marsh. In 1981-1983, fixed and floating tire breakwaters were constructed and used as erosion control structures. Models of these were first tested in wave-generating flumes at WES, and the best configurations were used in field experiments. Breakwaters were anchored in front of the planted marsh to slow wave action. Their cost was approximately one-fourth that of conventional stone armor placement (Allen, Webb, and Shirley 1983).

44. In 1983-1986, experimental plots were planted, coupled with a variety of even less costly techniques (one-tenth to one-fourth less than stone armor). Smooth cordgrass transplants were planted in burlap plant rolls, in various thicknesses of erosion control mat, in grid mattress, and in anchored tires belted together across the intertidal area (Allen, Webb, and Shirley 1984; Webb, Allen, Shirley 1984). The burlap plant rolls and 7.5-cm thicknesses of erosion control mat provided the most stability for smooth cordgrass transplants while they were establishing (Allen, Webb, and Shirley 1986). These later tested techniques worked as effectively as the more expensive floating tire breakwaters. Control areas were also planted each

Table 4

Plant Species Occurring on GI, Mobile Bay, Alabama

Species	Year First Occurred	Means of Occurrence	Remarks
Alligator weed	1982	Colonized	Uncommon
American sycamore	1982	Colonized	Uncommon, stressed
American three-square	1982	Colonized	Scattered stands
Bahia grass	1982	Seeded	Common, abundant at some locations
Baldcypress	1982	Planted	Uncommon, stressed
Barnyard grass	1982	Seeded	Common, abundant inside dikes in low-lying areas
Beach morning glory	1983	Colonized	Uncommon
Beach panic grass	1982	Colonized	Common
Big cordgrass	1983	Colonized	Scattered stands
Big smartweed	1983	Colonized	Uncommon
Bitter mint	1984	Colonized	Uncommon
Bitter panic grass	1982	Seeded	Scattered stands
Black needlerush	1985	Colonized	Uncommon in low-lying areas
Black willow	1982	Colonized	Isolated small trees
Broom sedge	1983	Colonized	Common
Browntop millet	1984	Colonized	Uncommon
Cabbage palm	1983	Planted	Stressed or dead
Chufa	1984	Colonized	Scattered plants
Chinese tallow	1983	Planted	Stressed
Cocklebur	1984	Colonized	Scattered plants
Colorado river hemp	1985	Colonized	Uncommon
Common Bermuda grass	1982	Seeded	Abundant on all undisturbed dikes
Common crabgrass	1982	Seeded	Common
Common purslane	1983	Colonized	Uncommon
Common ragweed	1982	Colonized	Common on all dikes
Common reed	1982	Planted	Small to large stands on all dikes
Dallis grass	1983	Colonized	Uncommon
Dandelion	1984	Colonized	Uncommon
Day flower	1985	Colonized	Uncommon
Dog fennel	1981	Colonized	Common, abundant in some nesting areas
Eastern baccharis	1983	Colonized	Uncommon
Eastern red cedar	1983	Planted	Stressed, uncommon
Eurasian watermilfoil	1984	Colonized	Uncommon
Fall panic grass	1982	Seeded	Common, abundant in some dike areas
Giant reed	1983	Planted	Uncommon
Globe nutsedge	1982	Colonized	Common on all dikes

(Continued)

(Sheet 1 of 3)

Table 4 (Continued)

Species	Year First Occurred	Means of Occurrence	Remarks
Goosefoot	1984	Colonized	Common on NW dike
Green ash	1983	Planted	Stressed or dead
Ground nut	1984	Colonized	Uncommon
Horse nettle	1983	Colonized	Common on all dikes
Japanese pittisporum	1983	Planted	Stressed or dead
Jewelweed	1984	Colonized	Uncommon in wet areas
Johnson grass	1985	Colonized	Uncommon
Knotroot bristlegrass	1983	Colonized	Common
Leafy three-square	1985	Colonized	Uncommon in wet areas
Live oak	1983	Planted	Trees growing well
Longleaf pine	1983	Planted	Trees growing well
Marsh fleabane	1984	Colonized	Uncommon
Mimosa	1983	Planted	Stressed or dead
Nutsedges	1981-83	Colonized	Common
Nuttall's oak	1983	Planted	Stressed or dead
Parrot feather	1985	Colonized	Uncommon in wet areas
Peppergrass	1985	Colonized	Uncommon on dikes
Pokeweed	1984	Colonized	Uncommon
Red rattlebox	1983	Colonized	Uncommon
Rose mallow	1986	Colonized	Rare
Saltgrass	1981	Colonized	Common on all dikes
Saltmarsh aster	1982	Colonized	Common on all dikes
Saltmarsh bulrush	1981	Colonized	Abundant in wetlands
Saltmarsh sand spurry	1982	Colonized	Uncommon
Saltmarsh morning-glory	1982	Colonized	Uncommon
Saltmeadow cordgrass	1982	Colonized	Common in wetlands
Sand bur	1985	Colonized	Uncommon
Sandgrass	1982	Colonized	Common in some dike areas
Saw grass	1985	Colonized	Uncommon in wetlands
Sea oxeye	1984	Colonized	Uncommon
Sea purslane	1981	Colonized	Common
Seaside goldenrod	1982	Colonized	Common
Seaside heliotrope	1985	Colonized	Uncommon on dikes
Sedges	1982	Colonized	Uncommon on dikes
Slash pine	1983	Planted	Trees growing well
Slender arrowhead	1985	Colonized	Uncommon in wetlands
Smartweeds	1981	Colonized	Common on all dikes
Smell melon	1982	Colonized	Uncommon, east dike
Smooth cordgrass	1981	Planted	Abundant in wetlands
Softstem bulrush	1983	Colonized	Scattered stands
Southern cattail	1982	Colonized	Common in wetlands
Southern magnolia	1983	Planted	Stressed or dead
Sow thistle	1984	Colonized	Uncommon on dikes
Sprangle top	1983	Colonized	Common on dikes

(Continued)

(Sheet 2 of 3)

Table 4 (Concluded)

Species	Year First Occurred	Means of Occurrence	Remarks
Sweet gum	1983	Planted	Stressed
Trailing wildbean	1982	Colonized	Common, abundant on south dike
Vasey grass	1985	Colonized	Uncommon
Water hemp	1984	Colonized	Common on dikes
Water hyacinth	1983	Colonized	Uncommon, washed up on beaches
Watermelon	1982	Colonized	Uncommon on dikes
Water smartweed	1984	Colonized	Uncommon in wetlands
Water purslane	1983	Colonized	Uncommon in wetlands
Water willow	1984	Colonized	Uncommon
Wax myrtle	1982	Colonized	Also transplanted in 1983, growing well
Widgeongrass	1984	Colonized	Uncommon in pond
Wild carrot	1985	Colonized	Uncommon on dikes
Wild lettuce	1984	Colonized	Uncommon on dikes
Yankee weed	1982	Colonized	Common, abundant in some areas
Yellow nutsedge	1983	Colonized	Common on dikes

(Sheet 3 of 3)

year so that a valid statistical comparison could be made. Details of these experiments and techniques are presented in Allen, Webb, and Shirley (1983, 1984, 1986) and Allen (1988).

45. In spite of washout incidence of some plant propagules from storm and wave action, by 1986 the northwest dike intertidal area had been effectively stabilized as a result of the original plantings, replanting of washout areas, and spread of surviving sprigs throughout the planted area (Figures 7 and 8). On the south dike, a combination of both washout and subsidence destroyed the first plantings in 1983. Subsequent test plots were somewhat successful. However, wave action and wind fetch were greater on the south dike than on the northwest dike, and erosion problems on most of the south dike could not be readily solved using existing biostabilization technology. A combination of stone armor and vegetation was stabilizing the south dike in 1987 at the completion of WES long-term monitoring.

46. An interesting phenomenon of the planted saltmarsh on the northwest dike is that it trapped large quantities of sand from Mobile Bay. After winters in which smooth cordgrass had died back because of cold weather and sand had simultaneously accumulated, portions of the saltmarsh appeared to have been smothered. However, each year the marsh grew through the sand berm that formed and appeared to grow farther out into the bay. This has slowly expanded the width of the marsh and the stability of the northwest dike.

47. In conjunction with this sand accumulation, swales formed behind the berms. These swales colonized with brackish marsh plants, primarily American three-square, saltmarsh bulrush, and southern cattail. Propagule sources for these species were marshes on the mainland over 3.2 km away. On the south dike where subsidence occurred, resulting brackish ponds also colonized with these same species.

48. Planted dike areas. Mobile District stabilization efforts using vegetation were limited to the upland portions of the dikes, and the District initially aerially seeded grass seeds onto the crests and slopes of the dikes in the spring of 1982. These included bitter panic grass, barnyard grass, bahia grass, common Bermuda grass, fall panic grass, and common crabgrass. Survival of original seeds was primarily on the outer slopes of the dikes where seeds were sheltered from wind and waves by driftwood and flotsam. Gaining a foothold in these locations, these species spread over much of the dikes, especially the stoloniferous species, and particularly on the south and

Figure 7. Planted saltmarsh at GI after two growing seasons, planted behind a floating-tire breakwater

Figure 8. Saltmarsh at GI after five growing seasons. Note the width of the marsh--only a small fringe was actually planted, and the rest spread from those plantings

northwest dikes. By 1984, dike crests on undisturbed portions of the dikes had nearly 100-percent plant covers largely dominated by common Bermuda grass. These grass stands were heavily mixed with naturally colonizing species of trailing wildbean, yankee weed, dog fennel, and sea purslane. On dike areas where upgrading and stabilization work was necessary, vegetation was buried but recovered with the same species over a period of 1 to 2 years.

49. In 1983, the District hired a landscape contractor to plant a variety of selected native and exotic tree, shrub, and grass species on all three dikes. These included baldcypress, cabbage palm, Chinese tallow, common reed, eastern red cedar, giant reed, green ash, Japanese pittisporum, live oak, longleaf pine, mimosa, Nuttall's oak, slash pine, and southern magnolia. A number of these plants were not adapted to such hot dry windy conditions, and they died within the first year. A number of others were buried from dike upgrading of the east and south dikes or were lost from subsidence of portions of the south dike. The majority of the survivors were slash and longleaf pines and live oak on the south and northwest dikes and common reed on the south dike. After dike stabilization is complete, if natural colonization of woody vegetation has not occurred, the District is considering the option of replanting upland areas with native coastal tree and shrub species to provide some woody vegetation on GI. However, dense stands of woody vegetation would displace the seabirds that have nested in early successional stage habitats on GI since its construction, and this would be taken into consideration before planting additional woody vegetation.

Long-Term Management Plans

50. Mobile District plans to continue with the approach of long-term management for GI, which will include calling meetings of the permanent interagency working group established in 1987 on an as-needed basis. The CDF draft long-term management strategy is being finalized by the District and includes engineering features such as erosion protection structures, cross-dikes, and dewatering potential and environmental features such as habitat development using dredged material placement, management and protection of waterbird nesting colonies on GI, pond management for feeding areas, continued innovation in the area of shoreline protection using saltmarsh, and chronological long-term documentation of wildlife and vegetation on GI.

Summary

51. Seven-year-old GI replaced 525 aquatic ha of Mobile Bay with a combination of island, wetland, and upland habitats. The island CDF significantly increased in its natural resource value each year, while providing a long-term containment site for dredged material from Theodore Channel and US Navy Homeporting. It provided a testing site for important wetland development studies using biostabilization techniques and contributed highly significant nesting habitats for seabirds of the northern gulf coast. Long-term management of GI by the Mobile District has allowed continued wildlife and fish use of the CDF while concurrently being used frequently for placement of large quantities of dredged material.

PART III: POINTE MOUILLEE, WESTERN LAKE ERIE, MICHIGAN

Background

52. The Pointe Mouillee (PM) habitat development field site is located on the western shore of Lake Erie, Michigan, (Figure 9) and is part of the Pointe Mouillee State Game Area owned by the State of Michigan Department of Natural Resources (MDNR). This part of Lake Erie has great historical significance in the settlement of the Detroit area and has been used for wildlife hunting since the first settlers arrived on Lake Erie shores.* Over a period of about 40 years, the barrier beach that had protected the game area had eroded and been overtopped, resulting in severe erosion in the PM marshes. Lake level rises also had a significant impact on the erosion problem. At the same time, sediment sources from the Huron River that nourished the PM marshes were essentially stopped because of the construction of dams and reservoirs along the river's length. Over 1,618 ha of marshes and game area was flooded, and much of it was lost to open water.

53. At the same time that these erosive forces were working, the Detroit District had a need to build a CDF to hold contaminated dredged material from the Lake Erie Ship Channel (USAED, Detroit 1974). A cooperative effort between the District and the MDNR resulted in development of a 365-ha CDF that was designed to the configuration of the old barrier island (Figure 10) and that would provide long-term protection to the eroding game area marshes. All construction costs, including construction of some of the habitat development features, were funded by the Detroit District. The game area continues to be managed by personnel of MDNR who are permanently staffed at PM State Game Area.

54. A low-level, long-term monitoring effort by WES was funded as part of DOTS because this site was representative of a large Great Lakes CDF that held contaminated silty sand dredged material and that could be coupled with ongoing disposal operations and an ongoing natural resource management plan. In 1979-1980, WES also addressed the feasibility of using dredged material to

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* MDNR, 1979, "Environmental Impact Statement for the Restoration of the Point Mouillee Marshes and for Subsequent Development and Management of the Entire Pointe Mouillee State Game Area," Draft Report submitted to the USAED, Detroit, Detroit, MI.

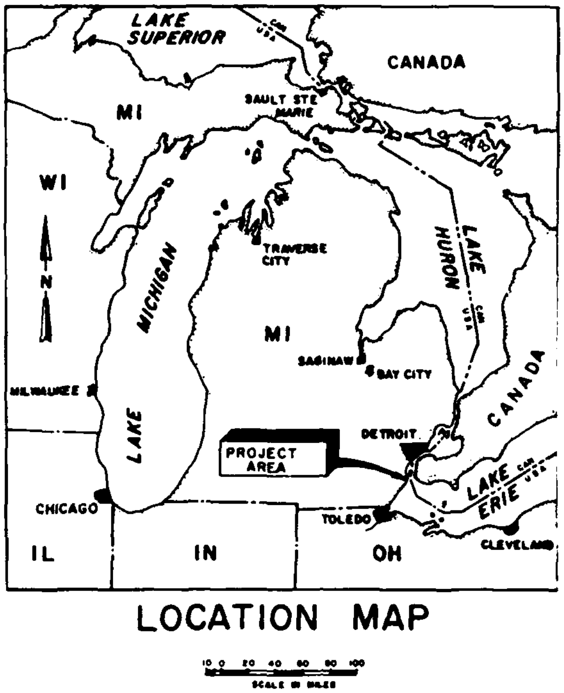


Figure 9. Pointe Mouillee CDF in western Lake Erie, Michigan

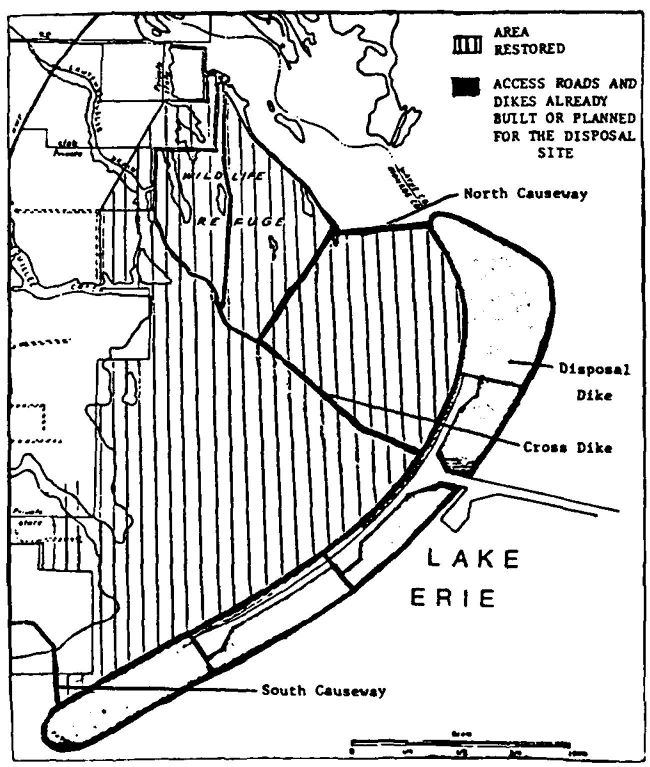


Figure 10. Pointe Mouillee configuration, crossdiking, access roads, and state game area

create more marsh, for general habitat development, and to build nesting islands for Great Lakes waterbirds and waterfowl under a separate request from the District (Landin 1982).

55. The PM project has a number of ongoing, long-term objectives. The primary objectives are: (a) to protect and stabilize the wetlands and shoreline inside the state game area; (b) to reestablish the marsh through encouragement of sedimentation and plant colonization; (c) to establish a multiuse site on both the CDF and the game area that includes a visitors' center, waterfowl and small game hunting, fishing, boating, bird watching, hiking, jogging, and similar activities; and (d) to provide a place to dispose of maintenance dredged material from western Lake Erie harbors and channels. To accomplish these objectives as efficiently and as cost effectively as possible, a draft long-term management plan for PM was developed while construction was under way (Landin 1982). Features such as culverts to allow water to flow through the marsh, access crossdikes, dredged material island formation within the game area for nesting waterfowl and waterbirds, and intensive wildlife management were incorporated into the long-term plan. The potential impacts of the construction activities and dredged material placement on existing conditions were also examined.

Site Development

56. The CDF dike, crossdikes, and access road construction was completed in 1983 and has a projected life of 10 to 20 years. Access roads and dikes were heavily armored (Figure 11) to prevent wind and water erosion, and the dikes were constructed to be as impermeable as possible to prevent possible leakage of material from the CDF. Large culverts were installed in each access road to allow water to flow through the marsh. These culverts effectively slowed down flow and allowed sediment to drop out within the game area.

57. One of the more important features at PM carried out by the District is protection of the entire area through locked gates that barricade access roads to unofficial vehicular traffic. Access is allowed to foot and bicycle traffic only, and in the marsh closest to the CDF and on the CDF itself, no hunting is allowed. Fishing and other passive recreation such as bird watching, jogging, and biking are allowed by both the MDNR and the CE.

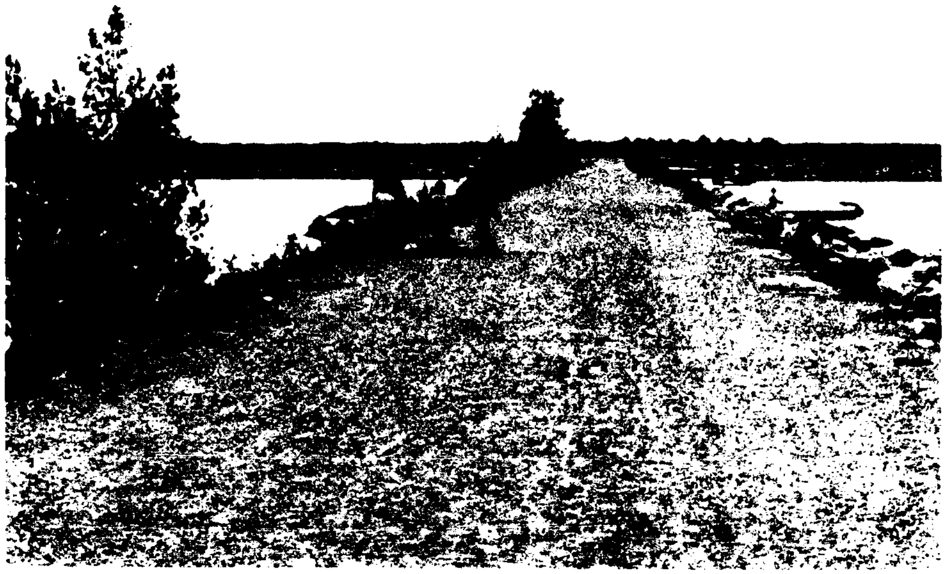


Figure 11. Exterior and interior of all dikes in the CDF and exterior of access crossdikes were armored with heavy stone underlain with erosion control fabric to prevent failure of the dikes

Use of the CDF dikes is allowed but not encouraged until the CDF is filled and dredging activities are completed.

58. Monitoring at PM was always a low-level effort because of funding and manpower constraints and consisted of seasonal observational data on wildlife, vegetation, and site changes in both the protected marsh and the CDF. Transects for vegetation data were established and sampled across the two southernmost compartments of the CDF. No fisheries or other aquatic data were collected as part of this study, although interviews with local fishermen and recreationalists were conducted each year.

Marsh restoration and development

59. Culverts to slow water flow allowed eroded areas to begin ebuilding and recolonizing with marsh and aquatic plants. Controlled sedimentation had not resulted in as much large-scale emergent marsh development as anticipated through 1987, primarily because of continued high lake levels which began to recede that year. However, over 400 ha of protected habitat with floating and rooted aquatic vegetation has resulted (Figure 12).

Figure 12. The eroding marsh within the state game area has been stabilized as the result of protection provided by the CDF and is recovering gradually

60. Nearly 1,100 ha of high marsh/wetland meadows that had been impacted by the eroding shoreline marshes has also been protected and is currently being used as hunting and nature areas by MDNR. Extensive food crops for waterfowl and other wildlife are planted and allowed to stand in the fields to encourage resident and migratory animal use of the PM game area. This effort is entirely a part of MDNR management, but the Detroit District is kept informed as to activities and management plans so that it can coordinate and better plan ongoing disposal and site operations.

Habitat development in the CDF

61. Within the 365-ha CDF, an estimated 60 ha of emergent cattail and bulrush and high marsh, primarily common reed, has developed through 1987. The CDF is divided into four major compartments with crossdikes (Figure 10). Disposal began at the southern end of the CDF, and this compartment has essentially been filled with the exception of the northeast corner that remains as a freshwater pond. Between 1980 and 1985, the fringes of this compartment grew into a dense stand of common reed, which was used as a red-winged blackbird nesting site (Table 5). Blackbirds of all species also used the common reed extensively for roosting in large numbers. The center of this

Table 5

Wildlife Species Observed in Site Visits to Pointe Mouillee, Michigan, 1978-1987

Species	Season Observed*	Behavior and Remarks
	Birds	
Common loon	Fa	In protected marsh
Pied-billed grebe	Sp,Su,Fa	Nested in marsh
Double-crested cormorant	Su,Fa	In open water of CDF
Great blue heron	Sp,Su,Fa	Nested in game area
Green-backed heron	Sp,Su,Fa	Nested in game area
Cattle egret	Su	On CDF dike
Great egret	Sp,Su,Fa	Nested in game area
Black-crowned night-heron	Sp,Su,Fa	Nested in game area
Whistling swan	Sp,Fa	In protected marsh
Canada goose	Sp,Fa,Wi	In CDF and game area
Mallard	Year-round	Nested in protected marsh
American black duck	Year-round	Nested in protected marsh
Gadwall	Sp,Fa	In protected marsh
Northern pintail	Sp,Fa	In protected marsh
Green-winged teal	Fa	In CDF ponds
Blue-winged teal	Su,Fa	In marsh and CDF ponds
American widgeon	Sp,Fa	In protected marsh
Northern shoveler	Fa	In protected marsh
Wood duck	Sp,Su,Fa	Nested in game area and CDF
Redhead	Fa	In open water in CDF
Ring-necked duck	Fa	In protected marsh
Canvasback	Sp,Fa,Wi	In open water in CDF
Lesser scaup	Sp,Fa	In open water in CDF
Common goldeneye	Wi	In protected marsh
Bufflehead	Fa	In open water in CDF
Ruddy duck	Sp,Fa	In protected marsh
Hooded merganser	Fa	In protected marsh
Common merganser	Sp,Fa	In open water in CDF
Red-breasted merganser	Fa	In protected marsh
Sharp-shinned hawk	Sp,Fa	Over marsh and CDF
Red-tailed hawk	Year-round	Nested in game area
Broad-winged hawk	Sp,Fa	In game area and marsh
Rough-legged hawk	Wi	In game area
Northern harrier	Fa	Over protected marsh
American kestrel	Year-round	Nested in game area
Ring-necked pheasant	Year-round	Nested in game area
Sora	Fa	In game area
Common gallinule	Su	Nested in protected marsh

(Continued)

* Sp = spring; Su = summer; Fa = fall; Wi = winter

(Sheet 1 of 4)

Table 5 (Continued)

Species	Season Observed	Behavior and Remarks
American coot	Sp,Su,Fa	Nested in protected marsh
Semipalmated plover	Fa	In CDF
Piping plover	Fa	In CDF
Killdeer	Sp,Su,Fa	Nested on CDF
Black-bellied plover	Sp,Fa	In CDF
Ruddy turnstone	Fa	In CDF
American woodcock	Su	Nested in game area
Common snipe	Su,Fa	Nested in protected marsh
Whimbrel	Fa	On CDF dike
Upland plover	Fa	In CDF
Spotted sandpiper	Sp,Su,Fa	In CDF and protected marsh
Solitary sandpiper	Sp,Su,Fa	In protected marsh
Willet	Fa	In CDF
Greater yellowlegs	Sp,Su,Fa	In CDF
Lesser yellowlegs	Sp,Su,Fa	In CDF
Pectoral sandpiper	Sp,Fa	In CDF
Least sandpiper	Sp,Fa	In CDF and marsh shores
Dunlin	Sp,Su,Fa	In CDF
Short-billed dowitcher	Sp	In CDF
Long-billed dowitcher	Fa	In CDF
Semipalmated sandpiper	Sp,Fa	In CDF
Marbled godwit	Fa	In CDF
Sanderling	Fa	In CDF
American avocet	Fa	In CDF
Great black-backed gull	Fa,Wi	On CDF dikes
Herring gull	Year-round	Nested on CDF dikes
Ring-billed gull	Year-round	Nested on CDF dikes
Bonaparte's gull	Sp,Fa	Over CDF
Forster's tern	Su,Fa	Feeding over marsh
Common tern	Sp,Su,Fa	Nested on CDF dikes
Caspian tern	Su,Fa	Resting on CDF dikes
Black tern	Sp,Fa	Over marsh and CDF
Mourning dove	Year-round	Nested in game area and CDF
Yellow-billed cuckoo	Su	Nested in CDF
Screech owl	Year-round	Nested in game area
Great horned owl	Year-round	Over game area and CDF
Common nighthawk	Sp,Su,Fa	Nested in game area and CDF
Chimney swift	Fa	Over marsh and CDF
Belted kingfisher	Sp,Su,Fa	Feeding in marsh and CDF
Yellow-shafted flicker	Sp,Su,Fa	Nested in game area
Red-headed woodpecker	Sp,Su,Fa	Nested in game area
Yellow-bellied sapsucker	Fa	In game area
Downy woodpecker	Year-round	Nested in game area
Eastern kingbird	Sp,Su,Fa	Nested in game area
Great crested flycatcher	Sp,Su,Fa	Nested in game area
Traill's flycatcher	Sp,Su,Fa	Nested in game area

(Continued)

(Sheet 2 of 4)

Table 5 (Continued)

Species	Season Observed	Behavior and Remarks
Least flycatcher	Sp,Su,Fa	Nested in game area
Eastern wood peewee	Sp,Su,Fa	Nested in game area
Horned lark	Fa,Wi	In CDF upland
Tree swallow	Su,Fa	Feeding over marsh and CDF
Bank swallow	Su,Fa	Feeding over marsh and CDF
Rough-winged swallow	Su,Fa	Feeding over marsh and CDF
Barn swallow	Sp,Su,Fa	Nested in game area
Purple martin	Sp,Su,Fa	Nested in vicinity of PM
Blue jay	Year-round	Nested in game area
Common crow	Fa	Feeding in CDF
House wren	Sp,Su	In game area
Marsh wren	Sp,Su,Fa	Nested in marsh and CDF
Gray catbird	Sp,Su,Fa	Nested in game area
Brown thrasher	Sp,Su,Fa	Nested in game area
American robin	Sp,Fa	In game area, marsh, and CDF
Swainson's thrush	Fa	In game area
Eastern bluebird	Su	Nested in game area
Blue-gray gnatcatcher	Fa	In protected marsh
Ruby-crowned kinglet	Fa	In game area
Cedar waxwing	Fa	In CDF
European starling	Year-round	Nested in game area
Red-eyed vireo	Sp,Su,Fa	Nested in game area
Warbling vireo	Sp,Su,Fa	Nested in game area
Prothonotary warbler	Su	Nested in protected marsh
Nashville warbler	Sp	In game area
Yellow warbler	Sp,Su,Fa	Nested in game area and CDF
Magnolia warbler	Sp	In game area
Cape May warbler	Sp	In game area
Black-throated blue warbler	Sp	In game area
Chestnut-sided warbler	Sp	In game area
Pine warbler	Sp	In game area
Prairie warbler	Sp	In game area
Palm warbler	Sp	In game area
Ovenbird	Sp,Fa	In game area and CDF
Northern waterthrush	Sp	In protected marsh
Common yellowthroat	Sp,Su,Fa	Nested in game area
Wilson's warbler	Sp	In game area
American redstart	Sp	In game area
House sparrow	Year-round	Nested at MDNR offices
Bobolink	Su	Nested on CDF
Eastern meadowlark	Sp,Su,Fa	Nested in game area
Red-winged blackbird	Sp,Su,Fa	Nested in marsh and CDF
Northern oriole	Su,Fa	Nested in game area
Rusty blackbird	Fa	In CDF reeds
Common grackle	Sp,Su,Fa	Nested in game area
Brown-headed cowbird	Sp,Su,Fa	Nested

(Continued)

(Sheet 3 of 4)

Table 5 (Concluded)

Species	Season Observed	Behavior and Remarks
Northern cardinal	Year-round	Nested in game area
Rose-breasted grosbeak	Fa	In game area and CDF
Indigo bunting	Sp,Su,Fa	Nested in game area
American goldfinch	Year-round	Nested in CDF and game area
Rufous-sided towhee	Year-round	Nested in game area
Savannah sparrow	Sp,Su,Fa	Nested in game area and CDF
Vesper sparrow	Su	In CDF
Tree sparrow	Fa,Wi	In game area and CDF
Chipping sparrow	Fa	In game area and CDF
Field sparrow	Su,Fa	Nested in game area and CDF
White-crowned sparrow	Sp,Fa	In game area
White-throated sparrow	Sp,Fa	In game area and CDF
Fox sparrow	Fa	In game area and CDF
Swamp sparrow	Sp,Su,Fa	Nested in game area
Song sparrow	Sp,Su,Fa	Nested in game area and CDF
Snow bunting	Wi	In game area and CDF
	Mammals	
Beaver	Sp,Su,Fa	In protected marsh
Muskrat	Sp,Su,Fa	In protected marsh and CDF
Eastern cottontail	Year-round	In game area and CDF
White-tailed deer	Su	In game area and CDF
Raccoon	Su,Fa	In game area, marsh, and CDF
Woodchuck	Sp,Su,Fa	On CDF dikes
Small rodents (mice, voles, and shrews)	Sp,Su,Fa	In game area, CDF, and marsh

(Sheet 4 of 4)

compartment was higher than the fringes and over the same period colonized with a mixture of low-growing herbs and grasses such as reed canarygrass and red clover and with small cottonwood trees (Table 6). The small pond that remains was fringed with cattails and bulrushes. This southernmost compartment was intended to be capped with clean topsoil after it was filled and dewatered, but this action appears to now be unneccessary since the sandy dredged material contains few contaminants. Growth of plant species such as cottonwood and common reed that are not used as food by wildlife in this region also effectively limited impacts to feeding wildlife.

62. The middle compartment was also partially filled and has remained primarily as a large freshwater pond fringed by cattails and bulrushes, although parts of it are filled above the water table and have colonized with herbs, grasses, and small cottonwood trees. Both of these compartments are used by local citizens for fishing, even though there is no access to fish from the lake or the marsh and even though no fish-stocking has occurred. When interviewed, these fishermen report that their primary catches are perch and catfish or bullhead, all of which are known to be transported as eggs and fry by herons and egrets. These fishermen also report that fishing is generally much better in the marsh behind the CDF, as would be expected. In the marsh behind the CDF, fishermen report catching bluegill, bullhead, catfish, walleye, northern pike, perch, and sheepshead. Carp are also very common.

63. Both of these ponded areas are used extensively by feeding herons and egrets, primarily great blue herons, great egrets, and black-crowned night-herons (Table 5). Waterbirds in a heronry within the state game area are the primary feeders. Ring-billed gulls and herring gulls that nest in small numbers on the outermost dikes of the CDF each year also feed within these ponds as well as in the protected marsh.

64. The northernmost, largest compartment is currently being filled with channel maintenance dredged material. Most of the area is a shallow, unvegetated pond, with extensive mud flats. Each year during migration, thousands of shorebirds and waterbirds frequent this compartment to feed and rest (Table 5). This has especially been the case when a dredge was actively unloading material, with gulls feeding on tidbits coming from the dredge pipe. Because of this heavy avian use, birding clubs from Michigan, Ohio, and Ontario, Canada, come to PM on a regular basis and walk 1 to 2 km to this

Table 6

Plant Species Identified at the Pointe Mouillee Site According to Habitat

Species	Habitat, Location, and Remarks
Black willow	Edge of marsh, CDF
Eastern cottonwood	Game area, CDF, edge of marsh
Black birch	Game area
Hawthorn	Game area
American elm	Game area
Staghorn sumac	Game area and CDF
White ash	Game area
Beech	Game area
Silver maple	Game area, edge of marsh
Box elder	Game area, CDF, edge of marsh
Apple (escaped)	Game area
Peach (escaped)	Game area
Mulberry	Game area
Rose mallow	Edge of marsh
Elderberry	Edge of marsh, game area
Red-osier dogwood	Game area, CDF, edge of marsh
Raspberry	Game area and CDF
Grape vine	Game area
Virginia creeper	Game area and CDF dikes
Water plantain	Game area, CDF, edge of marsh
Loosestrifes (several spp.)	Game area, CDF, edge of marsh
Smartweeds (several spp.)	Game area, CDF, edge of marsh
False nettle	Game area and CDF
Mint	Game area and CDF
Wild rice	Edge of marsh
Native red clover	On CDF dikes
Fescues (three spp.)	CDF and game areas
Reed canarygrass	CDF
Broadleaf cattail	Marsh and CDF ponds
Softstem bulrush	Marsh and CDF ponds
Rice cutgrass	Edge of marsh and CDF ponds
Blue jointgrass	Edge of marsh
Sago pondweed	In protected marsh
Floating-leaf pondweed	In protected marsh
Flowering rush	In edge of marsh and CDF
Duckweeds	In protected marsh
Wild oats	In game area
Sedges (several spp.)	Game area, marsh, CDF
Nutsedges (several spp.)	Game area and CDF
Rushes (several spp.)	Edge of marsh
Bladderwort	In protected marsh and CDF ponds
Coontail	In protected marsh and CDF ponds
Parrot feather	In CDF ponds
Burreed	In protected marsh
Milkweed	Game area and CDF
Butterfly bush	Game area

(Continued)

Table 6 (Concluded)

Species	Habitat, Location, and Remarks
Ironweed	Game area and CDF
Sweet clover	Game area and CDF
Queen Anne's lace	Game area and CDF
Blue vervain	Game area and CDF
Dock (several spp.)	Game area, edge of marsh, and CDF
Burdock	Game area
Field thistle	Game area and CDF dikes
Canada thistle	Game area
Rudbeckia	Game area
Marestail	Game area and CDF upland
Skullcap	Game area
White water lily	In protected marsh and CDF ponds
Wild morning glory	Game area and CDF
Dodder	Game area
Cinquefoil	Game area and CDF dikes
Horse nettle	Game area and CDF
Goldenrods (several spp.)	Game area and CDF
Jewelweed	Edge of marsh
Spurges (two spp.)	Game area and CDF
Water celery	In protected marsh

compartment to bird watch with spotting scopes. When this compartment is filled in several years, it will be allowed to naturally colonize with vegetation similar to the previously mentioned compartments.

65. The last compartment to be filled at PM will be the middle compartment, which allows barge access. This compartment is deep enough to accommodate fully loaded barges of dredged material, which were subsequently off-loaded across the crossdikes into compartments to the north or to the south. Monitoring in this compartment was very limited, but the area was entirely protected and water accessible from the lake and was frequently used by gulls and terns for feeding and resting. In addition, during summer months, as many as five recreational boats of small to medium size could be found at any given time fishing within this middle compartment.

66. Data collected from vegetation transects, where 5 to 10 random quadrats were sampled (depending upon the length of the transect), indicated that plant colonization took place in the two southernmost compartments within three growing seasons. The colonization rate was dependent upon available water, and fringes of cattail and bulrush quickly formed around ponded areas,

while common reed colonized quickly around the toes of the dike interiors. This colonization was slow on the higher portions of the compartments where the dredge pipe was placed, and more mounding occurred. In 1987, these areas were still not showing 100-percent vegetation cover similar to the fringe areas of cattail, bulrush, and reed. A list of the most common plant species found in the quadrats is given in Table 7, indicating frequency of occurrence.

67. The PM area is used by over 200 species of wildlife.* Many of these species were observed during long-term monitoring (Table 5). The most common wildlife observed were 145 species of birds. Many of the small birds that frequented the protected marsh and state game area did not use the CDF, as was expected since successional stages of vegetation at the CDF were very early and still somewhat disturbed, with very little shrub/tree cover. Bird use of the CDF in winter was extremely limited, although a few black ducks were sighted on ponds inside the middle compartments that had not completely iced over.

68. Resident mammals were commonly seen, especially in summer months along the dikes and access roads. These included beaver, muskrat, raccoon, woodchuck, eastern cottontail, small rodents (mice, voles, and shrews), and an occasional white-tailed deer. Although red fox, weasel, mink, and skunk are known to live in the PM area, none were observed during site visits. Only eastern cottontails were observed during site visits during winter months, where snow and ice were deep and the only human recreational activity in the vicinity of the CDF appeared to be occasional ice fishing.

Long-Term Management Plans

69. In general, both the MDNR and the Detroit District are following the long-term management plan drawn up during the 1970s. Record lake levels and state budget problems have caused changes in expected timetables for marsh development and for construction of walks, visitors' center, and a few other important features of the overall PM site. The Detroit District will continue to use the PM CDF for disposal of dredged material, to carry out its protective and funding role in management activities, and to cooperate with the MDNR on natural resource management ventures.

* MDNR, op. cit.

Table 7

Frequency of Occurrence and Percent Cover of Commonly Observed Plants in CDF Quadrats at Pointe Mouillee in Summer 1987

Species	Percent Cover	Frequency of Occurrence, %
Blue jointgrass	1.3	6.3
Black willow	4.2	12.5
Blue vervain	1.0	6.3
Burdock	1.8	25.0
Butterfly weed	0.5	12.5
Canada thistle	0.2	25.0
Cattail	8.5	25.0
Common reed	12.7	67.5
Cutgrass	6.7	37.5
Cypress spurge	0.2	6.3
Dandelion	0.3	67.5
Dock	1.4	50.0
Eastern cottonwood	2.9	12.5
False nettle	0.7	25.0
Field thistle	0.3	12.5
Flowering rush	2.5	25.0
Four-o'-clock	2.4	12.5
Goldenrod	3.4	37.5
Horsetail rush	2.8	12.5
Indian hemp	0.1	6.3
Jewelweed	0.7	50.0
Knotweed	1.3	67.5
Loosestrifes	2.2	75.0
Milkweed	1.6	37.5
Mint	0.9	12.5
Morning-glory	0.6	6.3
Mulberry	0.1	6.3
Native red clover	1.8	12.5
Nightshade	0.9	12.5
Queen Anne's lace	2.8	37.5
Plantain	1.4	25.0
Red maple	0.1	6.3
Reed canarygrass	2.3	50.0
Rose mallow	0.4	25.0
Rudbeckia	0.6	12.5
Silverleaf cinquefoil	0.2	6.3
Skullcap	1.1	12.5
Smartweeds	5.5	100.0
Softstem bulrush	4.8	25.0
Staghorn sumac	0.9	6.3
Sweet clover	0.8	12.5
Tall fescue	4.6	12.5
Virginia creeper	0.3	6.3
Wild oatgrass	1.7	67.5
Wild rice	0.1	6.3
	Mean Quadrat Cover = 91.6%	

70. The MDNR currently carries out a year-round schedule of recreational and management activities at PM, and this is expected to continue at the present level of effort. For example, game management employees plant extensive food crops for waterfowl and other wildlife. The MDNR has established trails, fishing piers, picnic facilities, a marina, a temporary visitors' center, and hiking and jogging areas. Fishing has always been the most common recreational use, and hunting is allowed during season. In the future, MDNR also plans to fluctuate water levels for vegetation manipulation within the protected marsh and to provide more fishing and additional day-use facilities such as trails and picnic areas.

Summary

71. The PM site was built to be and is functioning as a multipurpose beneficial use site. Long-term monitoring and interviews with site users of the 1,862-ha site indicated that six events occurred over time:

a. Soon after it was placed, dredged material was colonizing with herbaceous vegetation of both wetland and upland species, primarily cattail, bulrush, and common reed.

b. The PM site was receiving ever-increasing wildlife and fish use by resident, migratory, and nesting species as a direct result of the protection provided by the CDF and by management.

c. The PM site was finding wide acceptance by local and regional citizens for recreational purposes such as bird watching, hunting, fishing, boating, hiking, biking, and jogging.

d. The CDF was carrying out its purpose of holding maintenance dredged material as intended as an ongoing CE activity and had a number of years' life left for additional material placement.

e. Emergent marsh vegetation was slowly increasing inside the eroded wetland behind the CDF, but not as quickly as anticipated because of recent record-high lake levels.

f. The sandy texture of the dredged material was allowing leaching below the root zone within the CDF, increasing nonavailability of possible contaminants.

PART IV: LAKE OF THE WOODS, WARROAD, MINNESOTA

Background

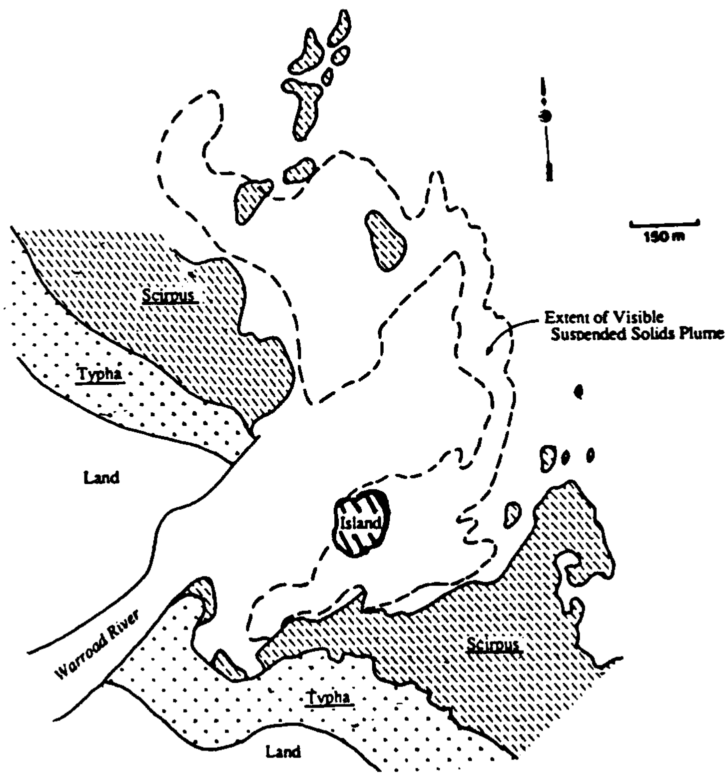
72. The Lake of the Woods (LW) field site is located at Warroad, MN, at the mouth of the Warroad River Harbor, in Lake of the Woods, a boundary lake between the United States and Canada (Figure 13). This site was selected for long-term study because it is a freshwater lacustrine island and is located in a region of the United States where ice and short growing seasons are factors to consider in habitat development (Landin 1985).

73. The 2-ha LW island was planned and built by the St. Paul District in 1983. This is the newest and the smallest of the 11 field sites examined in this report. The site is being monitored in a joint effort among the St. Paul District, the Minnesota Department of Natural Resources (MNDNR), and WES, with the bulk of the field data being collected by the District and the MNDNR.

74. Until 1983, dredging of the Warroad Harbor was accomplished by sidecasting hydraulically pumped material within the river and lake edge. The decision to pump material into just one area to allow an island to form was a joint agreement with the District, the CE, the MNDNR, the FWS, and the City of Warroad to demonstrate habitat development in a cold freshwater lake using dredged material. Resource agencies had expressed opposition to sidecasting in the river and lake, and upland disposal sites were not available. Dredging in Warroad Harbor is on a 7-year cycle. Data collected from the island development will be used to determine if future dredged material can be placed onto or adjacent to the existing site for additional habitat development (Wilcox 1988).

75. Lake of the Woods is a remnant of the once extensive glacial Lake Agassiz. Lying on the border between Minnesota and the Canadian provinces of Manitoba and Ontario, the lake covers 3,846 sq km. The Minnesota portion of the lake has simple morphometry, a mean depth of 5.4 m, and an extensive littoral zone. Water levels are regulated to between 323.5 and 321.9 m National Geodetic Vertical Datum (NGVD) by international treaty. The southern portion of the lake is eutrophic and supports a popular year-round sport fishery for walleye and northern pike (Wilcox 1988).

a. The general location of the field site



b. The location in relation to the channel

Figure 13. Lake of the Woods field site, off the mouth of Warroad Harbor, Minnesota (after Wilcox 1988)

76. The southern shore of the lake has been shaped by littoral sediment drift. Maximum wind fetch distance is 48 km to the northeast. The beach profile is shallow, with the 3-m contour lying approximately 1,600 m offshore. The shoreline near Warroad has remained stable during historic times. An offshore sandbar exists approximately 900 m from the shore. The net littoral drift of sediment resulting from wave action along the coast of the lake is to the southeast. Sediment transport is estimated to be about 50 percent greater in a southeasterly direction than in a northeasterly direction, or about 17,127 and 11,700 cu m, respectively (Hickock and Associates 1977).

77. Sediments vary from silt and clay offshore to sand in the beach zone. Submerged aquatic vegetation such as pondweeds and water celery occurs nearshore in shallow water areas. Softstem bulrushes grow in dense stands that extend out into the lake. Dense stands of cattail and reed canarygrass occur closer to and along the shore.

78. Benthic macroinvertebrates in the littoral zone of LW are most abundant in finer sediments and in areas with submerged aquatic plants. Predisposal densities determined in 1981 ranged from 39 individuals/sq m on sandy substrates to 1,846 individuals/sq m in areas with aquatic plants. The amphipods *Hyallela azteca, Pontoporeia affinis*, chironomid larvae, several species of snails, and fingernail clams were the most numerous macroinvertebrates in the vicinity of the dredged material placement site (Wilcox 1988).

Site Development

Sediment analysis

79. Sediment from the approach channel was analyzed for physical and chemical properties, including bioassay tests. The material to be dredged was found to be primarily uncontaminated fine-textured sand, but with substantial amounts of silt and clay in some portions of the channel (up to 80 percent). However, concentrations of ammonia, chromium, lead, zinc, mercury, copper, nickel, and cadmium in unfiltered elutriates exceeded US Environmental Protection Agency (USEPA) chronic toxicity criteria for the protection of aquatic life. These relatively low concentrations would be diluted to below-criteria levels upon discharge of the dredged material. Elutriate concentrations were sufficiently low, however, to indicate that dredged slurry concentrations of these contaminants were diluted to below criteria levels immediately upon

discharge of material. Solid and suspended particulate bioassays using channel sediments and native test organisms did not detect any toxicity to the organisms exposed (Marking et al. 1980).

80. The St. Paul District originally planned to place the island southeast of the harbor approach channel and landward of the natural offshore bar. However, the MNDNR preferred that placement of the material be inside the littoral drift zone near the harbor mouth (Wilcox 1988).

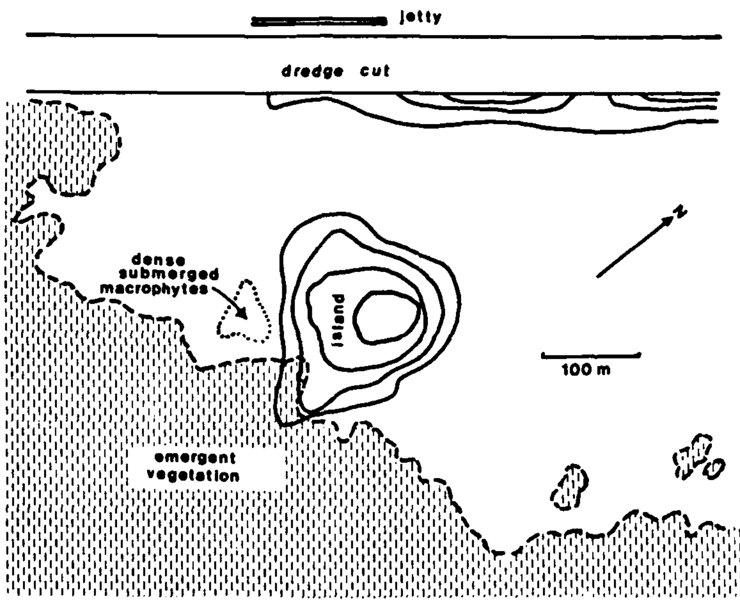
81. All dredging work was completed in June-July 1983 using a hydraulic dredge with a small discharge pipe equipped with a baffle to dissipate energy and spread the material as evenly as possible. The dredged material did not mound as much as anticipated because of the amounts of fine-grained dredged material encountered. However, a conical, 122-m-diam island was formed that initially settled to 1.5 m above mean low water (mlw) in LW (Figure 14). The lake level at the time of dredging was about 293.3 m NGVD.

82. Because of concern over water quality, aerial photographs were used to document the extent of the disposal plume. Plumes were found to vary greatly depending upon currents and wind, and the visible discharge plume varied from 16 to 49 ha in length while the dredge was in operation. Background suspended solids in the lake water were between 1 and 16 mg/ℓ. Suspended solids in the water column during dredging near the island fell to below 300 mg/ℓ within 61 m of the discharge pipe. Dissolved oxygen levels at all locations in the vicinity of the discharge remained at over 69 percent of saturation (Wilcox 1988).

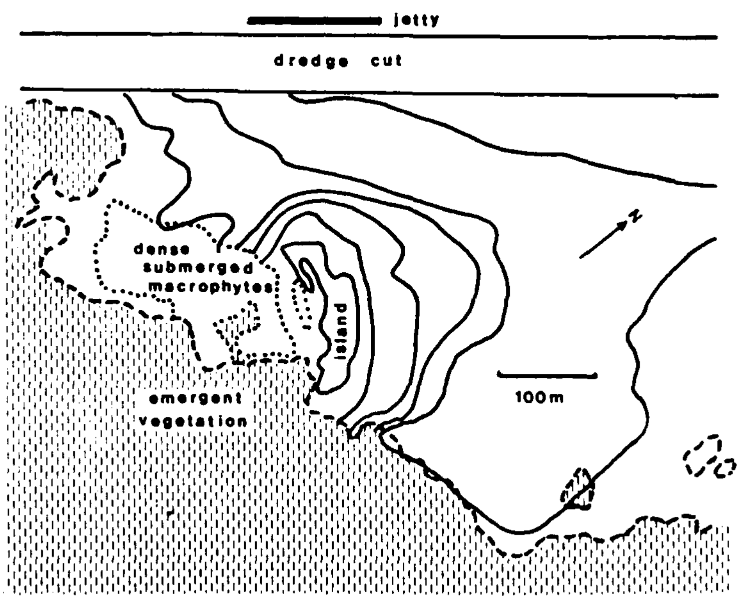
Vegetation

83. Plant species colonized the new island rapidly. Within the first growing season, a number of colonizing cattail and willow seedlings and other herbaceous wetland plants became evident. Lake of the Woods levels remained constant enough to allow colonization of dense emergent vegetation. This community was dominated by beggarticks, broadleaf arrowhead, cattail, and sandbar willow.

84. Because of unusually heavy rainfall in the northcentral United States and Canada, 1984 lake levels were higher than expected at the same time the island continued to settle. The LW site suffered considerable erosion and the effects of subsidence. This removed all but a small area of emergent vegetation, consisting of (in order of percent frequency) beggarticks,



a. Field site after placement in July 1983



b. Field site after current movement and subsidence in October 1984

Figure 14. The LW site changed in 1 year from a circular mound to a kidney-shaped island with adjacent mud flats and shallow water with dense aquatic vegetation (after Wilcox 1988)

broadleaf arrowhead, cattails, interior and other willow species, softstem bulrush, rushes, reed canarygrass. and smartweeds (Table 8).

85. Higher lake levels continued, and by October 1984, the LW site island had changed from a circular to a crescent shape, typical of an alluvial island produced by wave action (Duane et al. 1975). The placement location of the site prevented eroding material from accreting to the shoreline from littoral drift. Instead, eroding material formed a shallow sand flat on the lake side of the island, which remained unvegetated. Much of the island became submerged.

86. On the land side of the LW site, a dense bed of submerged aquatic plants formed because the island created a wave-protected zone. The most abundant plant species found growing in the aquatic bed included several pondweeds, parrot feather, water buttercup, and water celery, which were heavily fed upon by waterfowl.

87. The crest of the island was below water through much of 1985-1987, and wave erosion and subsidence had further reduced the top elevation of the island to about 292.2 m NGVD. However, the crescent shape of the island and the semicircular sand deposit lakeward of the island remained in spite of being underwater. By August 1987, three small spots of the LW site were once again emergent at lake elevation 292.0 m NVGD, and a series of low dunes and swales had developed on the sand flat lakeward of the island. Organic material and silt were trapped in these swales, and these pockets became densely vegetated with pondweeds, najas, and water celery.

Benthic macroinvertebrates

88. No quantitative benthic macroinvertebrate data were collected during island and sand flat colonization. However, general observations made by the MNDNR indicated that all indigenous macroinvertebrates had colonized the dredged material deposit, and species composition and densities of macroinvertebrates approximated predredging conditions within the first summer after island placement. Macroinvertebrates such as mayflies, caddisflies, and unionid mussels were all found on the LW site (Wilcox 1988).

Wildlife

89. The only wildlife noted using the LW site were birds, and various species began to use the island for resting as soon as the mound reached the water level surface in June 1983 (Wilcox 1988). Local birders who served as volunteer project observers reported 14 species of birds using the island in

Table 8

Vegetation on Warroad Dredged Material Island, 11 September 1984

Species	Frequency of Occurrence	Stem Height m	Stem Density per sq m
Beggarticks	87.5	1.20	19.7
Broadleaf arrowhead	81.2	0.80	13.2
Cattail	68.8	0.30	23.6
Sandbar willow	56.2	0.75	18.2
Willow sp.	25.0	0.75	15.0
Softstem bulrush	25.0	1.20	27.0
Spikerush sp.	18.8	0.30	61.3
Slender rush	12.5	0.30	8.0
Reed canarygrass	12.5	0.40	14.0
Water smartweed	6.2	0.20	4.0
Unid. broadleaf seedling	31.2	0.02	212.0
Unid. grass seedling	31.2	0.02	332.0

Source: Wilcox (1988).

1983. A total of 45 species of birds were observed using the island in 1984 (Table 9). Numbers of species declined after 1984 because of the island's submergence, but primarily continued to consist of gull and tern species, occasional great blue herons, and a number of migratory waterfowl and shorebirds.

90. The most numerous birds on the island during frequent observations made in the summers of 1983 and 1984 were ring-billed gulls, common terns, Franklin's gulls, white pelicans, double-crested cormorants, and herring gulls. Shorebirds occurred in groups of less than 10. As many as 472 birds were observed using the island at any given time (Wilcox 1988). From 1984 until the present, numerous ducks used the protected shallow water behind the LW site that had dense stands of aquatic vegetation for feeding and resting, and migratory shorebirds took advantage of falling water levels to feed on the exposed sand flats. No birds have ever been found nesting on the island in its 5 years of existence because of innundation and final island elevation.

Table 9

Birds Observed on the Dredged Material Island in Lake of the Woods at Warroad, MN, During 1984*

	4/28	5/2	5/3	5/6	5/12	5/17	5/20	5/22	5/26	6/3	6/7	6/9	6/11	6/13	6/18	6/24	7/7	7/19	7/28	8/11	8/17	8/24	8/30	9/5	9/9	9/11
American white pelican											30		4	15			14	20	4		6			2		
Double-crested cormorant																			25	35	35	25	250	11	13	
Great blue heron																										
Green-winged teal																		10				30	25			
Mallard											2			2		6			5	12	6			6	1	
Blue-winged teal											1		1									20	5	10	45	
Northern shoveler		2																								
Gadwall		2									1	1														
American wigeon	4																									
Lesser scaup	8	6																								
Common goldeneye										6		1	2													
Bufflehead																										
Osprey												1														
American coot	6																							30		
Black-bellied plover							2		1														10			
Semipalmated plover									2				19									1	5	5	4	
American avocet								2																		
Lesser yellowlegs	2																			1	3		6	5		
Marbled godwit										2										2						
Ruddy turnstone									2	1																
Red knot										3													1	3	3	4
Sanderling								6		15														4	2	2
Semipaulated sandpiper											2									5	4		6	6	2	
Least sandpiper												8									3		6	6	4	1
White-rumped sandpiper											2			1												
Pectoral sandpipe																										
Dunlin							12	6	2				1													
Stilt sandpiper																										
Long-billed																									2	
dowitcher																							1		1	
Dowitcher sp.																					5	4	10		1	
Franklin's gull						40				20		2			250				2							
Bonaparte's gull	2	6					1					1	2	50		40	1	12	2					4		
Ring-billed gull	425	200	300	200		50	100	25	20	10	8			4		3	1	45	70				6		3	
Herring gull	25							10	2	5	4		5			10	4		8		1		1	70		
Caspian tern						35			4								2		1	20	20	55	30			
Common tern											10	2		10		23		15	40	90	120	35	30	160	125	
Forester's tern	2	6		35	55	50	50							30		17			5	10	15	15		20	17	
Black tern									10			2		2									1		5	
Killdeer																			11	55		60	35	30	45	
Spotted sandpiper																						2	1	1		

Source: Wilcox (1988).
* Species list is for 1984; however, no additional species were sighted using LW site from 1985 through 1987.

91. Although muskrats occur in LW, none have been observed on the LW site, and no muskrat mounds have been found. No other mammal use was observed.

Summary

92. The LW site will continue to be observed at the same low level of monitoring intensity for the near future. Data will be used to determine whether similar habitat development can be accomplished at Warroad. There was minimum short-term impact from the unconfined dredging operation on water quality in the vicinity of the site and no long-term impact.

93. The most difficult problem encountered with building the LW site was the fine texture of the dredged material, which prevented mounding. This resulted in a smaller island that was more prone to both erosion and subsidence.

94. The second problem encountered was one that could not be anticipated by any of the interested parties--the unusually high lake levels that continued from the summer of 1984 until 1987. While these lake levels caused inundation and reshaping of the island, the result was also the creation of an unvegetated sand flat on the lake side of the island, which was heavily used by shorebirds and seabirds for resting. The swales behind the island became densely vegetated with aquatic plants and was heavily used by feeding and resting ducks. While unanticipated, the results were considered positive.

95. The most important aspect of this project has been the opportunity to evaluate island habitat development under the circumstances found in LW. Careful planning, including allowance for movement of the deposited material over time from man-made islands in the nearshore zone, is needed for successful implementation of other island projects similar to LW. It appears reasonably certain that future habitat development using dredged material can be overcome without great difficulty.

PART V: SOUTHWEST PASS, LOWER MISSISSIPPI RIVER, LOUISIANA

Background

96. With the State of Louisiana losing some 142 sq km of coastal marsh and upland habitat per year (Gunn 1987), much of what was emergent fresh marsh and saltmarsh is becoming open water. Losses are generally attributed to lack of sediment from water overflow keeping the marshes nourished and to disturbance of existing marshes by the building of work-access canals that allow saltwater intrusion into freshwater areas. This intrusion has resulted in kill-off of fresh vegetation, and open water leads develop before more tolerant saltmarsh can colonize the damaged area.

97. The New Orleans District has used unconfined dredged material placement since the mid-1970s on a limited basis as a method for elevating shallow bay bottoms to allow natural growth of emergent marsh. This placement has occurred in several areas along the Louisiana coast where it is feasible for the District to build marsh using dredged material and has resulted in the development of more than 2,000 ha of man-made intertidal marsh. This marsh creation has occurred along the Intracoastal Waterway, the Atchafalaya Basin, the Mississippi River-Gulf Outlet, but primarily at Southwest Pass (SWP) in the lower Mississippi River Ship Channel.

98. Marsh has developed by natural colonization of the dredged material, which is placed at intertidal elevations through movement of the disposal pipe to prevent mounding. All dredging work has been done by the New Orleans District. The WES studied SWP because it was representative of marsh development using unconfined dredged material placement, with no accompanying seeding or planting of the site. This type of marsh development is the least costly method and is also the easiest to accomplish and to incorporate into a large-scale dredging project. Based on cost figures in Gunn (1987), the New Orleans District has been able to build marsh using this method with costs ranging from \$1.50 to \$3.00/cu m, or a cost of approximately \$1,012.00/ha of dredged material placed 30 cm deep (or \$3,150/ha 1 m deep). Limitations in District marsh development work have involved (a) the inability of the dredging equipment to pump distances farther and farther away from the channels, (b) having to shut down operations to move the dredge pipe after an intertidal elevation is achieved, (c) keeping an experienced watchful dredging

inspector onsite to be sure that correct elevations for marsh development result, (d) the dynamics of Louisiana's wetlands that cause continual subsidence of both natural and man-made marshes, and (e) the additional costs associated with the above items.

99. Montz* determined that emergent marsh could colonize dredged material that was placed below 0.83 m mean low gulf (0.59 m mean sea level (msl)). Montz also found that if elevations exceeded 0.83 m, a high marsh/shrub zone would colonize instead of emergent intertidal marsh. Therefore, placement of dredged material at correct elevations, taking into account subsidence, erosion potential, and natural and man-made buildup of alluvial soil, would result in the development of intertidal marsh in Louisiana wetlands. While it is not possible to replace marsh as fast as it is being lost in Louisiana, New Orleans District has been using dredged material for beneficial uses wherever it can.

Site Development

100. The SWP is a very large area (Figure 15), and many hundreds of thousands of cubic metres of dredged material have been placed off the channel at SWP to build marsh since 1970 (Figure 16). Long-term monitoring had two primary objectives: (a) to determine how much marsh had been built and how much had been lost since construction through subsidence and (b) to determine vegetation colonization rates and communities on existing dredged material sites in SWP.

101. Within the selected study area, which was limited to the western side of the channel and included five distinct placement areas, the District has built 883 ha of new intertidal deposits ready for colonization as marsh since 1970 (Table 10). Much of the documentation was accomplished using New Orleans District archival black-and-white aerial photographs taken on an annual basis (scale: 2.5 cm = 254 m) and digitizing the amounts of each type of marsh found using photographs from 2- to 3-year intervals. Ground truthing of aerial photographs served as verification to the accuracy of identifying

* G. N. Montz, 1977, "A Vegetational Study Conducted Along Southwest Pass in the Mississippi River Delta, Louisiana," Inhouse Technical Report, USAED, New Orleans, New Orleans, LA.

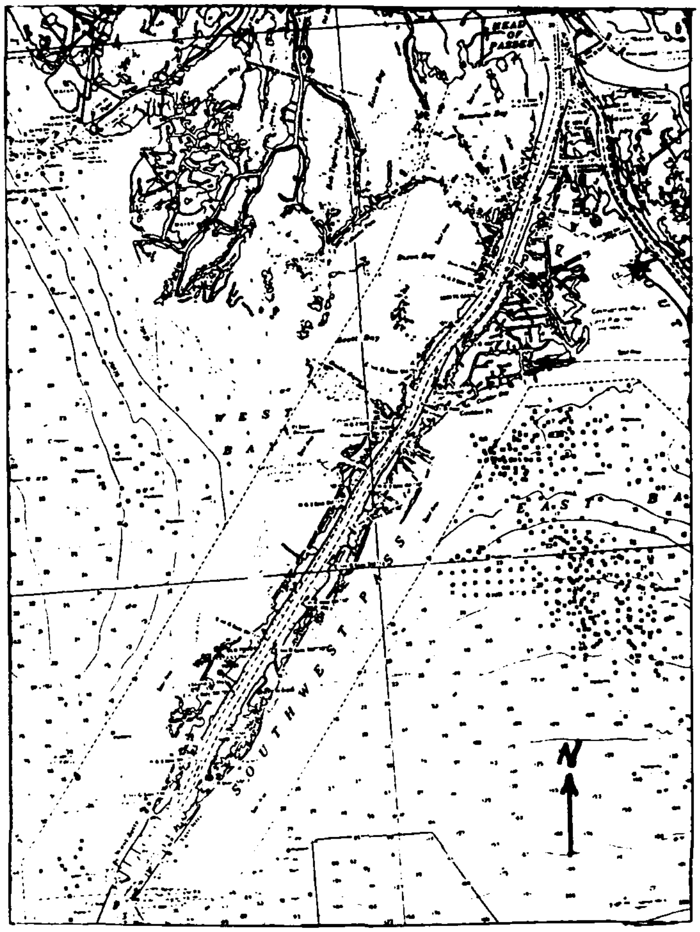


Figure 15. Southwest Pass, showing the marsh development taking place on the west side of the channel in Dixon Bay, Scott Bay, and West Bay below Head of Passes, Louisiana

vegetation types by photographs. Measurements in hectares included amounts of new dredged material, amounts of stabilized dredged material, amounts of marsh created in that period, amounts of previously created marsh that were stabilized, the amounts of marsh lost, and the net gain or loss of marsh.

102. In addition to analysis of aerial photographs from 1970 through 1986, a total of 22 transects from 150 to 500 m in length were set up across the five placement areas (more were surveyed, but the number analyzed was reduced to five since all could not be used for study in both years because of ongoing dredging operations) that were located from River Mile (RM) 5.6 to RM 15.5, all below Head of Passes (Table 11). Transects ran from the highest elevation at the channel down to mean low water across the dredged material

Figure 16. Vegetation colonizing a large dredged material deposit within the study area at Southwest Pass. The dark areas are emergent marsh plants growing in swales within the deposit

deposits. Along these transects, a total of 608 random quadrats were sampled in 1986 and 1987 to determine percent cover, colonizing species, and frequency of occurrence.

Analysis of long-term placement operations

103. Prior to 1970, New Orleans District generally used sidecasting within the river as its primary disposal method at SWP. There were a number of places where dredged material was placed along the banks of the river at SWP behind berms, and there was also considerable natural berm accretion along the banks of the river. Beginning in 1970, dredged material was pumped over the river berm and allowed to flow over shallow bay bottoms on the west side of the channel between RM 13.6 and 15.84 (exact number of cubic metres per year is not known). By 1973, additional dredged material had been placed between RM 13.6 and 15.84, and by 1976, numerous disposal "mounds" at an intertidal elevation could be seen on aerial photographs in this same area of SWP. Through this entire period, vegetation colonization as determined by the photos appeared to be relatively sparse but was increasing. However, the

Table 10

Created Marshes from Dredged Material and Changes at Southwest Pass, Louisiana, from 1970 through 1986 in Hectares

	1970-1978	1979-1984	1985-1986	Total
New dredged material deposits	497	191	195	883
Existing dredged material (prior to period)	--	748	731	295
Dredged material deposits lost to subsidence or erosion	161	12	0	173
Intertidal marsh created	274	168	22*	464
Stable intertidal marsh	--	465	454	919
Total hectares	932	1,584	1,402	2,734
Net gain or loss of marsh**	+290	+106	+12*	+408

* Photographs analyzed in 1986 did not account for the additional marsh development potential of the newest deposits of dredged material that at that time were bare but that were expected to colonize within 3 to 5 years.

** Numbers of net gain or loss were calculated from digitizing photographs for data indicating: [(existing marsh on old dredged material deposits) + (new deposits of dredged material colonized by marsh)] - [(losses of marsh due to subsidence) + (losses of existing marsh resulting from smothering by new deposits of dredged material)].

Table 11

Location, Number of Samples, Years of Disposal, and Remarks, Southwest Pass Study Area, 1986-1987

Site	Location RM	Transect No. and Distance	Quadrats Sampled	Year of Placement	Remarks
			1986		
1	5.6	3 (900 m)	93	1983	Disposal in 1977-1978 buried existing man-made marsh.
2	5.5	2 (400 m)	42	1983	
3*	5.3	1 (290 m)	30	1979	
4	10.2	3 (1,410 m)	144	1982	Created between 1973 and 1976. Disposed on marsh in 1982.
5	10.1	3 (590 m)	62	1986	Created between 1973 and 1976. Disposed on marsh in 1986.
6*	11.8	1 (480 m)	49	1982	Original deposit in 1973-1976. Disposed on marsh in 1982.
			1987		
1	5.6	2 (820 m)	84	1983	
4	10.2	2 (690 m)	44	1982	
5	10.1	3 (580 m)	59	1986	
8	9.0	2 (765 m)	45	1986	

* These two sites were not resampled in 1987 because of new deposits of dredged material and are not included in the vegetation table.

quality of the photos during this period made vegetation interpretation difficult.

104. From 1976 through 1979, most disposal did not appear to result in intertidal elevations. However, new marsh could be seen at RM 1.81, between RM 1.95 and 2.93, and between RM 5.0 and 6.0. Dredged material was placed over existing man-made marsh between RM 13.55 and 14.23 because care was not taken to extend the dredge pipe beyond existing marsh into the shallow water.

105. Deposits of dredged material from 1980 through 1986 resulted in numerous new intertidal areas being formed; subsequently, marsh development occurred. Two reoccurring problems could be readily seen on the aerial photographs, and New Orleans District has been working with their dredging inspectors to correct these. The first problem was that a considerable amount of existing man-made marsh was buried because the dredge pipe had not been extended far enough beyond existing marsh into shallow water areas. The second problem was that dredged material was sometimes allowed to mound above 0.83 m because the dredge pipe was not moved often enough. As a result, temporary "islands" were created that attracted large numbers of nesting seabirds until the islands became vegetated, not with intertidal marsh but with a high marsh/shrub community.

106. A total of 883 ha of intertidal dredged material deposits were created within the study area at SWP, with 497 ha formed from 1970 through 1978, 191 ha from 1979 through 1984, and 195 ha in 1985 and 1986 (Table 10). By 1986, 464 ha of these deposits had colonized with new intertidal marsh or other vegetation, but also by 1986, 172 ha of dredged material marsh and landmass of the earliest deposits within the study area had subsided. This dynamic marsh system, supplemented by new dredged material deposits, has resulted over a 16-year period in a new gain of 408 ha within the study area. No attempt was made to calculate the amount of landmass and marsh that would have actually been lost in the same 16-year period if no dredged material deposits had been placed on the west side of the channel within the study area. It is reasonable to assume that the loss would have been greater without the amount of new intertidal/landmass areas created because of the increased pressure of erosion and subsidence on the impacted marshes that existed there prior to 1970.

107. Analysis of the aerial photographs from 1979 through 1984 indicated that the reason for the low amount of actual landmass and marshes formed

during that period was primarily due to incorrect placement and elevation of the material. Diligence by New Orleans District personnel in monitoring dredging operations from 1985 through 1986 resulted in the creation of more marsh in these 2 years than had been created in the previous 6 years.

Colonization

108. Site ground truthing and monitoring verified Montz's* findings that if dredged material in Louisiana coastal areas is placed at the correct elevation, it will be colonized by emergent marsh. Colonization of new dredged material generally took place within a 5-year period, and fringes of smooth cordgrass marsh formed within one growing season at intertidal elevations on transects nearer to the Gulf of Mexico. Nearer to the Head of Passes, where water was almost entirely fresh, vegetation fringes tended to consist of such freshwater species as red-rooted sedge, mixed with smooth cordgrass (Table 12). Smooth cordgrass was absent from Sites 1 and 2 in 1986 because both had received new deposits of dredged material in 1983 at too high an elevation for smooth cordgrass to grow. The lower portions of both of these sites had colonized with a variety of freshwater wetland plants (Table 12), but common Bermuda grass was beginning to encroach over the highest points of both sites because of higher elevations above mean high tide.

109. The highest elevations of Sites 3, 4, and 5 also had considerable upland plant colonization (Table 12), and common Bermuda grass was frequently recorded in quadrats. Heliotropes, nutsedges, American three-square, common reed, camphorweed, and panic grass occurred in depressions on these sites.

110. Sites 4 and 5 had originally colonized as man-made intertidal marsh, but were buried with a new deposit in 1982 and again in 1986. As a result, when field work was conducted, almost no vegetation occurred on the highest portions of either of these sites.

Long-Range Development Plans

111. The long-range plan of New Orleans District is to continue placing dredged material at SWP and other channels where it is feasible to build or to nourish marsh. Part of the District's beneficial use objectives for dredged

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* Montz, op. cit.

Table 12

Frequency of Occurrence of Dominant Plant Species on Five Sites at Southwest Pass, Louisiana (in Percentages)

Plant Species	Site 1		Site 2		Site 3		Site 4		Site 5		Totals	
	86	87	86	87*	86	87*	86	87	86	87	86	87
Smooth cordgrass	0	6	0		8		75	31	75	2	100	39
Red-rooted sedge	9	42	2		12		26	8	2	18	55	68
Heliotrope	1	1	1		8		36	6	36	7	46	14
Common Bermuda grass	5	39	9		6		5	1	5	5	38	45
Water purslane	6	6	0		3		7	13	17	11	27	30
Sprangletop	10	26	5		6		1	0	1	0	22	26
Bigelow's glasswort	0	0	0		0		1	0	1	0	2	0
American three-square	2	10	0		12		0	2	0	7	14	19
Sea purslane	0	0	0		13		0	0	0	0	13	0
Common reed	3	2	0		0		0	1	0	4	13	7
Camphorweed	0	1	0		6		6	1	6	0	12	2
Marsh aster	0	0	0		10		0	0	0	0	10	0
Marsh goldenrod	0	0	0		0		3	1	3	0	8	1
Barnyard grass	2	6	4		2		0	0	0	0	8	6
Nutsedge spp.	3	0	4		0		0	0	0	0	7	0
Torpedo grass	0	6	0		3		0	3	0	7	7	16
Rattlebean	1	10	3		1		1	0	1	1	6	12
Orache	0	0	0		0		5	2	5	1	5	3
Lovegrass	0	0	0		0		5	0	5	8	10	8

* Sites 2 and 3 on this table were not resampled in 1987 because of new dredging work on those sites.

material from the New Orleans Channel Deepening and Widening Project authorized under the Water Resources Development Act of 1986 is to create up to 14,165 ha of new intertidal marsh. Continued maintenance dredging of SWP will result (a) in the development of marsh hectares similar in amounts to that created during 1985 and 1986 after the District had improved placement techniques and inspection efforts and (b) in several hundred hectares of new marsh each year in SWP. The District will also continue to consider marsh nourishment or creation in conjunction with other District coastal projects and is currently considering this beneficial use a part of an overall coastal erosion solution study.

Summary

112. Analysis of 16 years of aerial photographs from SWP and ground truthing and sampling indicate that in south Louisiana, unconfined dredged material placement is an economical, efficient method for creation or nourishment of intertidal marshes. Earliest efforts at SWP marsh development resulted in two problems that have been rectified--that of accidentally covering existing marsh and that of mounding the material too high to allow marsh to form.

113. Within the limited study area in SWP, nearly 500 ha of new marsh was created. Over the entire SWP area and other parts of coastal Louisiana, the landmass formation from dredged material was considerably greater. Subsidence of 172 has just within the study area since 1970 indicated that the SWP area is rapidly evolving and that if left alone, the existing marshes in SWP could be completely eradicated.

114. Nearer the gulf, smooth cordgrass was the primary colonizer of dredged material deposit fringes. Closer to Head of Passes, nutsedges, red-rooted sedge, and other freshwater species colonized. Dredged material deposits that had mounded at too high an elevation for intertidal marsh had colonized with common reed, panic grass, common Bermuda grass, heliotropes, and other species. However, it is expected that with the rate of subsidence taking place at SWP, any currently existing high marsh or shrub communities will gradually sink and become intertidal marsh over time.

PART VI: NOTT ISLAND, CONNECTICUT RIVER, CONNECTICUT

Background

115. The Nott Island (NI) habitat development field site is located in the Connecticut River, near Old Lyme, CT, on a 31-ha natural island that has received dredged material deposits for a number of years from maintenance dredging of the river channel (Figure 17). Nott Island, which is 10 km upriver from Long Island Sound, is intertidal, with saline to brackish influence on its wetland fringes. However, since this was the only entirely upland site of the 11 field sites studied, it was considered a freshwater site. The field site was a 3.2-ha portion in the highest part of NI (Figure 18).

116. Built by the New England Division during the DMRP, NI was constructed from an old disposal site that had not revegetated because of its sandy condition. Predisposal and early postdisposal studies were conducted by Connecticut College under contract to WES, and long-term monitoring studies through 1985 were conducted by the Environmental Laboratory at WES. Nott Island was selected for long-term study because it was representative of a high, sandy dredged material disposal site that had not revegetated after disposal and was located in the northeastern United States where maintenance dredging was necessary to maintain commercial and recreational boat traffic.

117. Early phase (1974-1978) studies included wildlife, vegetation, and soils and were documented in WES technical reports (Barry et al. 1978; Warren et al. 1978; and Hunt, Wells, and Ford 1978b). Midphase monitoring (1979-1982) was documented in Newling and Landin (1985). Engineering features of the NI site were detailed in Hunt et al. (1978a).

Site Development

118. The sandy disposal mound on NI was cleared and graded, and temporary, 1.0- to 1.5-m dikes were pushed up from the interior of the sand mound. This diked area was filled with 14,520 cu m of sandy silt dredged material from the channel and allowed to dewater. The two substrate types were then mixed using standard farming implements and a dozer. After thorough mixing, the site was limed, fertilized, and planted in experimental plots with

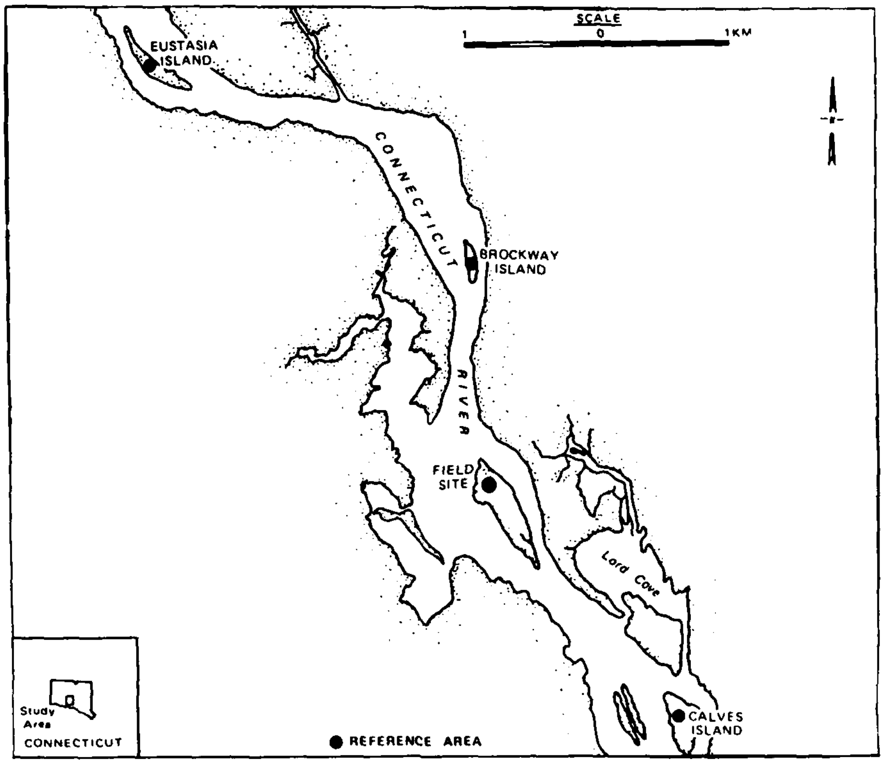

Figure 17. The NI field site in the Connecticut River, Connecticut

Figure 18. The NI field site prior to site development. The light area in the center of the island is the unvegetated sandy dredged material that became the study area

a goal of creating a nesting and feeding meadow for mallards, Canada geese, and other waterfowl.

119. Long-term objectives of the NI site were to (a) document the conversion of a previously unvegetated sandy disposal area into useful upland habitat and (b) monitor succession over time to determine degree of success or failure in the habitat development effort.

120. Early soils data were collected and analyzed for texture, pH, calcium, magnesium, potassium, phosphorus, organic matter, nitrate, ammonium nitrogen, and soluble salts. The site pH and potassium were found to be extremely low, with some sea salts remaining after a few months (just prior to planting) in the silt dredged material. All-purpose fertilizer was added to raise potassium levels, and lime was added to raise the pH.

121. The experimental plots were planted with a seed mixture of tall fescue, orchard grass, timothy, perennial ryegrass, native red clover, and white Dutch clover, with all remaining portions of the field site seeded with only tall fescue and white Dutch clover (Hunt, Wells, and Ford 1978b). Intensive sampling of vegetation from 1975 through 1977 included percent cover, stem height, natural colonization, stem density, phenology, above- and belowground biomass, and seed production (Barry et al. 1978, Warren et al. 1978).

122. These early studies indicated that while the grasses were generally successful in establishment on the field site, the legumes were not. Within the first growing season, orchard grass, perennial ryegrass, tall fescue, and timothy covered 80 percent of the test plots, while the two clovers planted reached less than a 20-percent cover. Legume failure was attributed to low pH despite liming, low potassium, and failure to use nitrogen-fixing inoculants with the clover seeds prior to planting, although these bacterial inoculants would probably have been destroyed by the low pH if they had been applied. By the end of the DMRP in 1978, tall fescue was the dominant species over the entire NI site, with orchard grass and timothy present only as minor associated species and some white Dutch clover remaining in isolated pockets. The densest, most robust growth occurred where the greatest amount of silt had originally been mixed with the sand (Newling and Landin 1985).

123. In preplacement and postplacement wildlife monitoring conducted by Connecticut College, mammals, birds, amphibian, and reptile populations on the NI field site were observed. Methods, analyses, and results of NI's wildlife

studies are detailed in Coastal Zone Resources Corporation (1977); Warren and Niering (1978); Warren et al. (1978); and Hunt, Wells, and Ford (1978b), and summarized in the following paragraph.

124. Eighty-five bird species were observed on the entire NI, and most were found using the field site at some time during early studies. Canada geese grazed the field site, and mallards nested there. Swallows, song sparrows, and mourning doves fed on the site. Red-winged blackbirds, marsh wrens, yellow warblers, and common yellowthroats nested in the trees and shrubs fringing the field site. Over the entire island, the greatest nest density was in the marsh close to the field site, while the greatest species diversity was found in the upland surrounding the field site. Nine species of mammals were found on NI. All used the field site for feeding. From 1974-1977, short-tailed shrew, eastern mole, white-footed mouse, meadow vole, short-tailed jumping mouse, raccoon, and white-tailed deer were found. These same species continued to live on NI through the completion of long-term monitoring in 1986. From 1978 through 1986, white-footed mice and eastern cottontails were also found. In addition, three amphibian species and six reptile species were found on NI.

125. In 1978, WES selected three natural islands with similarly unvegetated uplands in the Connecticut River to compare with the NI field site: Calves, Brockway, and Eustasia Islands (Figure 17). The same monitoring level of effort was employed at all four sites. From 1979 through 1986, monitoring consisted of site visits with Division personnel assistance, in which all wildlife and physical and environmental changes were recorded, and vegetation was both randomly sampled along transects and recorded in general observations of plant community changes on the site. Data collected in quadrats along transects consisted of percent cover, stem height, stem density, species composition, seed production, and estimate of vigor and health. No aboveground and belowground biomass were measured.

126. During the 1979-1986 monitoring, a number of general features and conditions were apparent. There was little change on any of the sites over the 8 years. Nott Island had declined from its initial vigor of the first 1 to 2 years of growth to a stable old-field condition by 1978 and continued to resemble typical old-field New England sites through 1986. On the other hand, of the three reference islands, Calves Island continued to be a dry, sandy, sparsely vegetated upland site; Brockway Island continued to develop slowly as

Table 13

Plant Species Recorded on Nott Island and the Three Natural Reference Islands from 1979 Through 1986

Nott Island Field Site

Alder 1,2*
American beachgrass 1
American three-square 1
Apple (escaped)1
Asiatic bittersweet 1,2
Asparagus (escaped) 2
Aster spp. 2
Barberry 1
Bayberry 1
Beggarticks 2
Bindweed 2
Black cherry 1
Black oak 1
Black willow 1
Bracken fern 2
Bull thistle 2
Buttonbush 1
Cocklebur 2
Common mullein 2
Common reed 1
Dandelion 2
Dayflower 2
Deertongue grass 2
Downy chess 2
Dwarf dandelion 2
Eastern cottonwood 1
Eastern red cedar 1,2
Evening primrose 2
Everlasting 2
Fall panic grass 2
False indigo bush 2
Foxtail grass 2
Glove nutsedge 2
Goldenrod 1,2
Grapes 1
Greenbrier spp. 1
Groundnut 2
Hawthorn 1,2
Lichen spp. 1,2
Lobelia spp. 1
Nutsedge spp. 1,2
Orchard grass 2
Panic grass spp. 1,2
Perennial pea 2
Perennial ryegrass 2
Pigweed 2
Poison ivy 1,2
Purple loosestrife 1,2
Pussytoes 2
Rabbitsfoot clover 2
Red maple 1
Red-osier dogwood 1,2
Redtop grass 2
River bulrush 1
Sandgrass 2
Sedge spp. 1,2
Six-weeks fescue 2
Skunk cabbage 2
Slough grass 1,2
Smooth cordgrass 1
Smooth sumac 1,2
Soft rush 1
Softstem bulrush 1
Staghorn sumac 1,2
Swamp milkweed 2
Switchgrass 2
Tall fescue 2
Tansy 2
Timothy 2
Tree-of-heaven 1
Vetch spp. 2
White Dutch clover 2
Wild lettuce 1,2
Wild peppergrass 1,2
Woodbine 2
Yarrow 2

(Continued)

* 1 = meadow fringe/trees/shrubs; 2 = planted meadow.

Table 13 (Concluded)

Nott Island Field Site (Continued)

Marestail fleabane 2
Moss spp. 1,2
Northern dewberry 1,2
Northern red oak 1

Calves, Brockway, and Eustasia Islands (Reference Islands Combined)

Alder
American germander
American three-square
Asiatic bittersweet
Bayberry
Beggarticks
Black gum
Black oak
Bull thistle
Cocklebur
Common mullein
Common reed
Dandelion
Deertongue grass
Eastern cottonwood
Eastern red cedar
Elderberry
Evening primrose
False indigo bush
Globe nutsedge
Goldenrod spp.
Groundnut
Hawthorn
Jewelweed
Winged sumac
Lichen spp.
Moss spp.
Long-spined sandspur
Marsh yellowcress
Morning glory spp.
Northern blackberry
Northern dewberry
Northern catalpa
Nutsedge spp.
Poison ivy
Pigweed
Pokeweed
Purple loosestrife
Red maple
Red-osier dogwood
Sandgrass
Sassafras
Six-weeks fescue
Skunk cabbage
Slough grass
Smooth cordgrass
Softstem bulrush
Staghorn sumac
Swamp milkweed
Switchgrass
Tree-of-heaven
Water hemp
Wild lettuce

a natural forest area; and Eustasia developed as a wet meadow because of a difference in water regimes between it and NI. Calves Island, an old, sandy dredged material deposit, remained unvegetated throughout the entire NI study and was most similar to the original deposit on NI. The plant community at NI has been virtually unchanged since 1978, with the only signs of gradual change the colonization along the fringes of the field site of a few eastern red cedars, alders, trees-of-heaven, and smooth sumacs.

127. Another gradual change has been that there is little remaining evidence of the original test plots because originally planted species have spread across plots. Species composition was similar in the plots to elsewhere in the meadow. Percent cover and plant vigor did not change, but there was a gradual shift to more dominance by the already predominant tall fescue, with a similar reduction in the amounts of timothy and orchard grass on the field site (Table 14). By 1986, white Dutch clover was gone from the meadow, and colonizers such as marestail fleabane, goldenrod, and bull thistle were found in old test plots.

128. There was a marked difference in wildlife use of the NI field site and the three reference islands through the end of the study. Without exception, at each site visit there were more wildlife species at higher population levels on NI than on any of the reference sites (Table 15). Between 1978 and 1986, there were over three times as many wildlife species on NI as on any of the reference islands. Stable populations of northern bobwhites, ring-necked pheasants, eastern cottontails, white-tailed deer, and a number of songbirds were evident, and while Canada geese did not continue to feed in the field site, they did use it for roosting and winter habitat.

Summary

129. The NI habitat development field site did not change from the grassy meadow it was intended to be when it was developed in 1974. After initial development, in which planted grasses thrived and the planted clovers did not, changes were gradual, with the meadow slowly resembling a typical New England old-field plant community. In comparison, the three reference islands also did not change. Likely because of the droughty nature of the soils, plant succession appears to occur at a very slow pace on these lower Connecticut River islands. The techniques developed during this study for restoration of high, dry sandy dredged material were demonstrated to have potential application to similar upland sites located in many US waterways.

130. In lessons learned at NI, the CE found that unless pH is adjusted to the correct range to allow adequate plant growth and reproduction, the success of upland sites such as NI could possibly not meet project habitat development objectives. Inoculation of clover and other legume seeds would

Table 14

Summary of Vegetation Data Collected on Transects at the NI Field Site, 1982, 1983, and 1985*

Species	Stems sq m	Stem Height, cm	Frequency of Occurrence, %	Percent Cover	Flowering Stems, No.
Tall fescue					
1982	166.4	43.4	87.5	15.1	75.5
1983	172.6	47.2	100.0	41.1	37.0
1985	170.3	46.5	100.0	49.2	59.5
Marestail fleabane					
1982	95.6	7.7	50.0	3.1	0
1983	84.3	6.9	12.5	1.3	0
1985	81.2	7.4	50.0	1.6	0
Globe nutsedge					
1982	32.4	19.3	12.5	1.5	15.5
1983	--	--	--	--	--
1985	16.7	21.5	12.5	1.1	8.5
Goldenrod spp.					
1982	1.0	16.5	12.5	0.3	0
1983	3.2	23.9	25.0	1.9	0
1985	2.7	21.7	25.0	1.8	0
Slough grass					
1982	--	--	--	--	--
1983	2.4	18.5	12.5	0.1	0
1985	--	--	--	--	--
Moss spp.					
1982	N/A**	N/A	75.0	18.6	N/A
1983	N/A	N/A	62.5	3.6	N/A
1985	N/A	N/A	75.0	13.9	N/A

* Summary based on data from eight 0.25-sq m quadrats each year.
** N/A = Not available for these species.

have also given leguminous plants a chance to succeed on the dredged material site.

Table 15

Wildlife Species Observed on Nott Island and Reference Islands from 1978 through 1986

Nott Island Field Site

Alder flycatcher 1,2*
American goldfinch 1,2
American robin 1,2
Bank swallow 1,2
Barn swallow 1,2
Belted kingfisher 1
Black-capped chickadee 1
Black duck 1
Blue jay 1,2
Brown thrasher 1,2
Canada goose 2
Chimney swift 2
American crow 1,2
Common grackle 1,2
Common yellowthroat 1,2
Double-crested cormorant 1
Downy woodpecker 1
Eastern kingbird 1,2
Eastern wood-pewee 1
European starling 1,2
Field sparrow 2
Fox sparrow 1,2
Gray catbird 1,2
Great black-backed gull 1
Great horned owl 1,2
Green-backed heron 1
Hairy woodpecker 1
Herring gull 1,2
American kestrel 1,2
Killdeer 2
Least sandpiper 1
Loggerhead shrike 1,2
Mallard 1
Marsh wren 1
Mourning dove 1,2
Mute swan 1
Northern bobwhite 1,2
Northern cardinal 1,2
Northern harrier 1,2
Northern mockingbird 1,2
Song sparrow 1,2
Spotted sandpiper 1
American tree sparrow 1,2
Tree swallow 2
Vesper sparrow 1,2
White-eyed vireo 1
Willow flycatcher 1,2
Wood thrush 1
Savannah sparrow 1,2
Yellow warbler 1,2
Ring-necked pheasant 1,2

Black racer 1,2
Eastern cottontail 1,2
Eastern mole 1,2
Meadow vole 1,2
Raccoon 1
Short-tailed shrew 1,2
White-footed mouse 2
White-tailed deer 1,2

(Continued)

* 1 = observed in meadow fringes; 2 = observed using planted meadow.

Table 15 (Concluded)

Nott Island Field Site (Continued)

Osprey 1
Purple finch 1,2
Red-winged blackbird 1,2
Northern rough-winged swallow 1,2
Ruby-throated hummingbird 1,2

Calves, Brockway, and Eustasia Islands (Reference Islands Combined)

Alder fycatcher
American crow
American goldfinch
American robin
Canada goose
Common yellowthroat
Fox sparrow
Gray catbird
Great black-backed gull
Herring gull
Killdeer
Mallard
Mourning dove
Northern cardinal
Northern mockingbird
Osprey
Red-winged blackbird
Savannah sparrow
Song sparrow

Meadow jumping mouse
Short-tailed shrew
White-footed mouse
White-tailed deer

PART VII: WINDMILL POINT, JAMES RIVER, VIRGINIA

Background

131. Windmill Point (WP), one of the first wetland sites built of dredged material during the DMRP, was begun in 1974. It is an 8-ha dredged material island in the James River, Virginia, located downriver from Hopewell, near Harrison's Bar (Figure 19). This project location was selected because it represented a freshwater, intertidal, riverine, Atlantic coast site and had very fine, hard-to-consolidate silty dredged material.

132. From its inception, WP was a cooperative effort. The site was selected by a consensus of the FWS, USEPA, National Marine Fisheries Service (NMFS), CE, and the Commonwealth of Virginia. Engineering and physical surveys and island construction were conducted by Norfolk District. The WES conducted the long-term environmental site monitoring. In addition to WES inhouse research, contracts for site research were awarded to Virginia Institute of Marine Sciences, Old Dominion University, Environmental Concern Inc., and Soil and Material Engineers Inc.

133. Island construction at the disposal site was begun in 1974 and completed in 1975. A temporary sand dike was hydraulically placed on the south side of the shipping channel to form a rectangular-shaped island (Figure 20). This material was taken from a sand pocket in the riverbed. In 1975, the island interior was pumped full of very fine-textured silty dredged material from the shipping channel (maintenance material), and the sand dike was breached to allow intertidal flow and the formation of tidal channels in the planned wetland.

134. A number of technical reports and papers presenting detailed information and data from WP and its reference areas have been published over several years. These include Adams, Darby, and Young (1978); Boesch et al. (1978); Diaz and Boesch (1978); Environmental Laboratory (1978); Garbisch (1978); Lunz (1978); Lunz et al. (1978b); Silberhorn and Barnard (1978); Cheng and Whitehurst (1984); Landin (1984); Newling and Landin (1985); US Army Corps of Engineers (1986); and Landin and Newling (1988). A summary of early and midphase findings is presented in the following paragraphs.

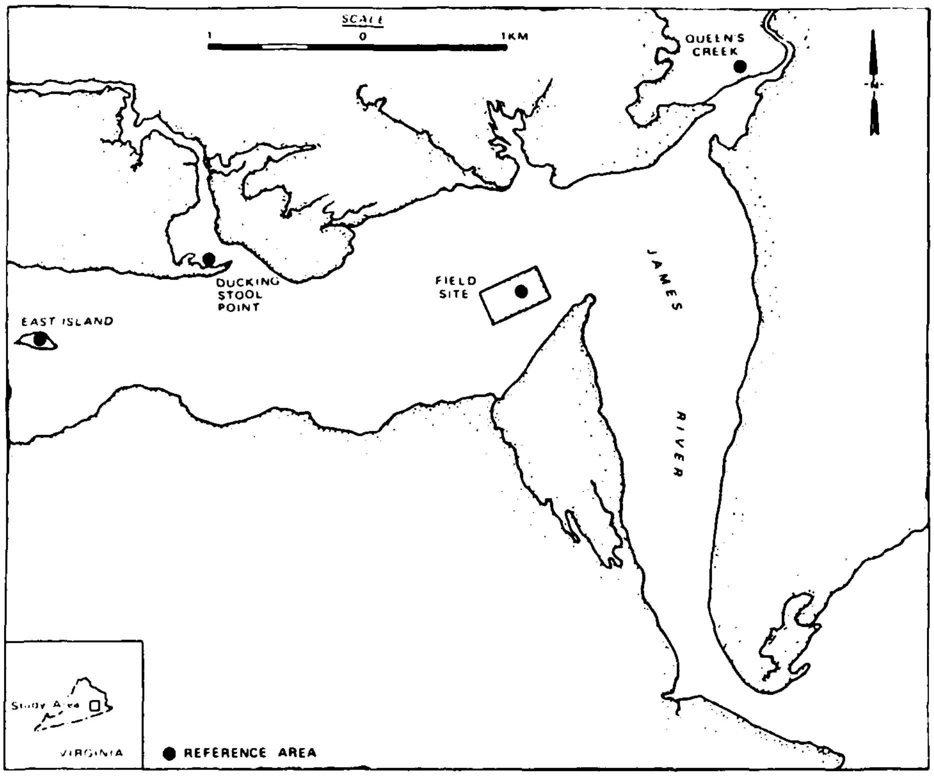

Figure 19. The WP habitat development site and its reference marshes in the James River, Virginia

Figure 20. The WP site 3 years after the sand dike and silty dredged material had been placed to form the island, showing interior wetland vegetation development

Site Development

1974-1978

135. Prior to island construction, baseline fisheries, wildlife, benthic, sediment, and water quality data were collected. During island construction and dredged material disposal, water quality was carefully monitored, including nitrate, nitrite, ammonium, phosphate, selected metals, volatile solids, total Kjeldahl nitrogen, total phosphorus, pH, Eh, cation exchange capacity, and sediment mineralogy (Adams, Darby, and Young 1978). Intensive postdisposal monitoring during the early phase of field site development included soils, vegetation (colonizers and planted species over time), fish and wildlife, benthos, and selected contaminants and physical island changes such as migration, subsidence, and erosion (Boesch et al. 1978, Diaz and Boesch 1978, Garbisch 1978, Lunz 1978, Lunz et al. 1978b, and Silberhorn and Barnard 1978). Also between 1974 and 1978, a nearby natural James River intertidal wetland at Herring Creek was selected and monitored along with WP for comparison purposes (Lunz et al. 1978b).

136. Vegetation. Originally, development plans called for planting a selected group of herbaceous wetland species on the dike and the interior of the island. However, while plants were being prepared for planting in 1975, the island interior began to rapidly colonize on its own with arrow arum, pickerelweed, broadleaf arrowhead, and other freshwater species. By the end of summer 1975, the island interior was densely covered with these plants, and no planting was attempted except for a very small area that was not successful. This test area was planted in July 1975 with tall fescue, orchard grass, ladina white clover, switch grass, and coastal panic grass (Garbisch 1978).

137. The sand dike was planted in 1975 with smooth cordgrass, big cordgrass, arrow arum, saltmarsh bulrush, and American three-square for the purpose of holding the dike in place until the island interior stabilized. Both the small test area inside the dike and the dike plantings were treated with various levels of fertilizer that over time proved to be of no apparent value, as both fertilized and unfertilized plantings responded and grew equally well at WP.

138. No woody plants were used, which, in hindsight, was a flaw in the planting design, because river water levels covered the herbaceous vegetation for extended periods of time (up to 3 months in the late spring/summer of

1983), and this eventually helped destabilize the dike. Woody plants would have grown to heights above river floods and would have developed more extensive root systems. A group of nearby dredged material islands that had colonized with woody vegetation more than 30 years ago was still stable in 1988.

139. Vegetation research during early years consisted of visual bimonthly estimation of plant cover and sampling of quadrats along randomly selected transects at both WP and Herring Creek. Sampling consisted of aboveground and belowground biomass, stem height, stem density, percent cover, species composition, and species invasion. Plant samples were oven-dried to a constant weight, weighed, and then ground in a Wiley Mill in preparation for analysis for nutrients and contaminants (Lunz 1978).

140. Although all plantings initially responded and grew well in 1975, intense Canada goose grazing coupled with washouts along the dike from ship and barge traffic and high river currents caused a continued decline in the plantings on the outer slope of the dike. However, natural invasion along the dike by a variety of herbaceous plants replaced those that were lost. In addition, test plots in the planted area inside the dike were generally successful in becoming vegetated (Silberhorn and Barnard 1978).

141. In addition to early vegetation monitoring, plant species lists were maintained chronologically to determine plant colonization of the island. A total of 75 plant species were found on the island in its first year of life (Lunz et al. 1978b), and the number of colonizers increased each year through 1979, when the plant species numbers stabilized (Newling and Landin 1985).

142. Soils. In general, sediments pumped into the site became more oxidized and contained less soil pore water and organic material than Herring Creek. Chemical changes in sediments appeared to have no effect on the wetland plant development at WP. Within 2 years after construction, soils at WP compared closely with those of Herring Creek. However, soils at WP never physically consolidated enough to support the weight of an adult human and made working in the site extremely difficult.

143. Contaminants. Samples of soil from WP and Herring Creek and of plants (barnyard grass, cattail, and arrow arum) were analyzed for five heavy metals (chromium, lead, zinc, cadmium, and nickel) and 14 other contaminants, including kepone, aldrin, dieldrin, endrin, chlordane, heptachlor, heptachlor epoxide, DDT, DDD, DDE, kelthane, lindane, methoxychlor, and polychlorinated

biphenyls (Lunz 1978). While several of these substances were found in the dredged material at WP and Herring Creek, only DDE was found to translocate to wetland plant shoots (Lunz 1978). Kepone was found to be relatively stable in the substrate and did not translocate into plants nor move deeper into the dredged material layers.

144. Fisheries and benthos. Fisheries data were collected through 1979 using a variety of apparatus, including Fyke nets, seines, and traps. Benthos samples were collected in a Ponar grab. To determine feeding impacts, sample sites included both unprotected sample stations and exclosures. These excluded feeding shorebirds and fishes that would have influenced the sample. Actual biomass of organisms was determined and compared for both sample sites. Asiatic clams, tubificid worms, and larval chironomids were the dominant organisms found, and WP had the greatest density of all four sites (Table 16). In 6 months after deposition of dredged material, benthos was found to be at predisposal levels (Lunz et al. 1978b).

145. Fish species found using the field site at various times of the year were largemouth bass, crappie, sunfishes, carp, channel catfish, white perch, striped bass, alewife, blueback herring, and American shad. Fisheries abundance and biomass were found to be approximately the same as at Herring Creek throughout sampling (Lunz et al. 1978b) (Table 17).

146. Wildlife. Since the WP site was underwater during predisposal monitoring, only occasional bird species were sighted at the location. After

Table 16

Approximate Densities of the 13 Dominant Taxa Averaged over All Samplings During the 1979 Season*

	Individuals/sq m	
Site	Marsh	Mud Flat
Windmill Point	4,600	700
Ducking Stool Point	1,700	1,200
East Island	3,200	1,600
Queen's Creek	2,100	650

* From Newling and Landin (1985).

Table 17

Total Abundance and Biomass (grams) of Fish Collected from the WP and Herring Creek Marshes

Location and Gear	Windmill Point			Herring Creek		
	Day	Night	Day	Night	Day	Night
Nekton Abundance						
Marsh Exterior						
Beach seine	665	2,693	3,358	1,038	920	1,958
Minnor traps	161	20	181	24	26	50
Subtotal	826	2,713	3,539	1,062	946	2,008
Marsh Interior						
Minnow traps	151	11	162	0	3	3
Gut Fyke net	323	72	395	36	135	171
Culvert Fyke net	9	32	41	--	--	--
Subtotal	483	115	598	36	138	174
Total	1,309	2,828	4,137	1,098	1,084	2,182
Total Biomass						
Marsh Exterior						
Beach seine	7,047.7	22,099.3	30,047.0	5,819.4	9,731.5	15,550.9
Minnow traps	852.6	190.9	1,043.5	237.4	202.7	440.1
Subtotal	8,800.3	22,290.2	31,090.5	6,056.8	9,934.2	15,991.0
Marsh Interior						
Minnor traps	586.3	97.2	683.5	0.0	14.5	14.5
Gut Fyke net	41,782.9	26,869.0	68,651.9	7,366.0	17,643.3	25,009.3
Culvert Fyke net	299.2	2,354.1	2,653.3	--	--	--
Subtotal	42,668.4	29,320.3	71,988.7	7,366.0	17,657.8	25,023.8
Total	51,468.7	51,610.5	103,079.2	13,422.8	27,592.0	41,014.8

Source: Lunz et al. (1978b)

WP was constructed, observations of birds and mammals were made bimonthly at both WP and Herring Creek. While some muskrat, house mouse, and marsh rice rat use was found during this phase of the study, primary use of WP was by 85 different species of birds (Boesch et al. 1978). These included Canada geese feeding on the newly emerging plants when the island was first built and heavy waterfowl and shorebird populations during migration. These birds fed in the marsh and on the adjoining mud flats.

147. Mallards and red-winged blackbirds nested on WP in 1976 and 1977. By contrast, wildlife use of the Herring Creek site was very different from WP, and almost no wildlife use was found, with no nesting occurring at all.

1979-1982

148. From 1979 through 1982, monitoring alternated between intensive and low-level efforts each year (Newling and Landin 1985). Because of limited funding for monitoring, benthos and fisheries monitoring was stopped after 1979, while other parameters (vegetation, soils, wildlife, physical changes, general environmental observations) continued to be measured. Also from 1979 through 1987, three other nearby natural wetlands in the James River, Queen's Creek, East Island, and Ducking Stool were selected and monitored for comparison to the WP site (Newling and Landin 1985). The Herring Creek site comparison was not continued because it was not as similar to the WP site as the three newly selected reference wetlands. Finding reference wetlands for WP proved to be very difficult, since few islands that are not wooded exist in the James River. Herring Creek, Queen's Creek, and Ducking Stool sites were all shoreline wetlands, while East Island was at least an island, but its age and origin were unknown (it is suspected to have been made of dredged material over 40 years ago) and it was located in a part of the river more protected from wind fetch.

149. Vegetation. In this midphase of site development, permanent vegetation transects were established at WP and at the reference sites. Randomly selected quadrats along these transects were sampled for aboveground and belowground biomass, stem height, stem density, percent cover, and species composition (Table 18). Percent cover was estimated at both the substrate level (intertidal) and the surface of the vegetation canopy (surface). Soil cores for belowground biomass sampling to depths of 30 cm mlw were collected and washed to remove plant material, which was then oven-dried to constant weights (Newling and Landin 1985).

Table 18

Summary of Vegetative Data Collected at the WP Habitat Development Site and Two Reference Areas on 20 July 1982

Species	Windmill Point				Queen's Creek				East Island			
	Stem Density Stems/sq m	Mean Stem Height cm	Frequency of Occurrence %	Mean No. Flowering Stems/sq m	Stem Density Stems/sq m	Mean Stem Height cm	Frequency of Occurrence %	Mean No. Flowering Stems/sq m	Stem Density Stems/sq m	Mean Stem Height cm	Frequency of Occurrence %	Mean No. Flowering Stems/sq m
Nodding beggarticks									12.5	154.8	100	0
Jewelweed					4.5	35.9	100	0				
Rice cutgrass					24.0	130.5	100	0				
Arrow arum					39.5	95.4	100	0	38.0	109.8	100	1.5
Pickerelweed	59.1	97.6	75	1.6								
Halberd-leaved tearthumb					23.0	116.6	100	0				
Broadleaf arrowhead									3.0	104.3	50	0
American three-square	5.4	64.8	25	1.5								
River bulrush					16.5	155.4	100	0				
Softstem bulrush	11.6	146.4	25	9.8								
Bur reed					0.5	176.0	50	0				
Big cordgrass	0.5	196.7	25	0.1								
Narrowleaf cattail	0.1	63.0	12.5	0								
Wild rice	16.5	236.5	50	2.1								
Southern wild rice									7.5	185.7	100	0
Total	93.2	126.8			108.0	118.3			61.0	128.1		
	Mean percent cover (surface): 56.3%				Mean percent cover (surface): 96.5%				Mean percent cover (surface): 95.0%			
	Mean percent cover (intertidal): 33.8%				Mean percent cover (intertidal): 67.5%				Mean percent cover (intertidal): 65.0%			

Source: Newling and Landin (1985).

150. Vegetation sampling during the midphase of the study indicated that stem density, stem height, and biomass at WP were within the range of variability of or greater than that of three reference areas, but that WP was lower in overall percent cover. Data for 1979, 1982, and 1985 are presented in Table 19. Elevation of the WP site during this time and thereafter was lower than the elevation of the three reference areas and continued to erode and/or subside.

151. By 1980, plant dominance was shifting to wild rice, which was beginning to become an obvious species within the WP plant community; in 1979, it had not been present at all. By 1981, wild rice dominated about 25 percent of WP, and by 1982, at least 60 percent of WP was covered with wild rice. There was never a corresponding increase in wild rice in the reference areas. This sudden change and later just-as-rapid decline in vegetation on WP gave a clear indication of WP instability and rapid site evolution taking place.

152. Between 1979 and 1982, 116 plant species were found growing on WP. Erosion and subsidence were constant factors affecting the island, and the dredged material inside the dikes never physically consolidated and stabilized. While the three reference areas continue to be relatively stable, the WP site at that point (1981-1982) appeared to be at its peak of development, based on plant productivity, maximum wildlife use, and sediment stability during 1981-1982. Vegetation along permanent transect lines on reference sites, while comparing favorably with WP in 1979 and 1982 (Tables 18 and 19), remained fairly constant in plant species composition. Even as the WP field site was beginning to erode in 1983, the reference sites were still relatively stable.

153. Soils. Soils at the WP site remained very soupy and never consolidated or physically stabilized throughout the entire study. However, soils found at Ducking Stool and portions of East Island were similarly unconsolidated. Amounts of plant biomass appeared to be very important in determining consolidation and trafficability on all of these very soft wetlands. Often, the only means of traversing these soupy areas was literally by stepping from plant clump to plant clump.

154. The instability of the WP soils behind the dike made the series of events from 1983 through 1987 almost inevitable. These events drastically changed the site's physical and environmental conditions.

Table 19

Comparison of Midsummer Trends in Stem Density, Stem Height, and Percent Cover Between the WP Habitat Development Site and Three Reference Marshes in the James River

Parameter	1979	1982	1985
Windmill Point			
Biomass, dry wt/sq m	2,008.2	N/A*	N/A
Mean stem density/sq m	211.5	93.3	117.4
Mean stem height, cm	112.0	126.8	126.5
Percent cover (surface)	46.8	56.3	51.9
Percent cover (intertidal)	33.3	33.8	N/A
Queen's Creek			
Biomass, dry wt/sq m	2,070.5	N/A	N/A
Mean stem density/sq m	380.1	108.0	265.3
Mean stem height, cm	111.8	114.8	117.3
Percent cover (surface)	90.7	96.5	91.6
Percent cover (intertidal)	59.3	67.5	N/A
East Island			
Biomass, dry wt/sq m	1,269.0	N/A	N/A
Mean stem density/sq m	183.3	61.0	98.2
Mean stem height, cm	98.6	128.1	111.8
Percent cover (surface)	65.1	95.0	90.0
Percent cover (intertidal)	43.4	65.0	N/A
Ducking Stool Point Marsh			
Biomass, dry wt/sq m	2,814.2	N/A	N/A
Mean stem density/sq m	253.0	N/A	234.4
Mean stem height, cm	101.3	N/A	104.9
Percent cover (surface)	79.9	N/A	74.3
Percent cover (intertidal)	[illegible]	N/A	N/A

* N/A = not available.

155. Fish and benthos. The last year of fisheries sampling occurred in 1979. In general, the same fish species that were found to be using the site from 1974-1978 were again found in 1979 (Newling and Landin 1985). In addition, carp were observed spawning in the island interior in large number. Table 20 indicates the presence of certain benthic species during caging (exclosure) studies conducted in 1979.

156. In 1979, benthic samples were collected using a Ponar grab. Sample sites included both exclosures and unprotected sample stations to determine feeding impacts. Asiatic clams, tubificids, and larval chirinomids continued to predominate. Meiobenthos were primarily nematodes and small crustaceans. On the three reference sites, meiobenthos were more abundant, while macrobenthos were most abundant at WP. In all, 5 years' data were collected on fish and benthos at WP and its reference sites (Lunz et al. 1978b, Newling and Landin 1985).

157. Wildlife. No additional bird species were found at WP during this period; however, raccoons were found to frequent the island, adding another mammal to the list of those using the site (Newling and Landin 1985). One of the more important species noted during this midphase was the bald eagle, which nested in James River shoreline trees and used the WP site for resting and its shallow waters for fishing.

158. Wildlife use of the sites was quite different. For example, large numbers of migratory shorebirds were observed each year feeding in the mud flats that formed at the downriver end of WP, but this did not occur on the reference sites. Wood ducks were observed using the Ducking Stool and East Island reference sites for night roosts, but this use was not observed at WP. Red-winged blackbirds, marsh wrens, and mallards nested at WP, and red-winged blackbirds nested at the three reference sites.

1983-1987

159. During this period, events seemed to overtake the emergent wetland at WP. In 1983, a temporary change in North American weather patterns caused extremely high rainfall amounts in the southeastern United States, which in turn caused rivers to remain at spring flood levels well into summer months. The WP site remained under water for several months, and the island dikes that had already breached widely prior to this event failed.

160. Vegetation. By 1985, much of the emergent marsh habitat on the permanent transect lines established on WP for vegetation evaluation washed

Table 20

Species Response to Caging Treatments, 1979

	Apr-Jun				Jun-Oct			
	HD*		DS		HD		DS	
Species	Marsh	Mud Flat	Marsh	Mud Flat	Marsh	Mud Flat	Marsh	Mud Flat
Branchiura sowerbyi		I**				I		
Limnodrilus spp.	I		I				I	
L. hoffmeisteri			I				I	
Peloscolex freyi			I	D				
P. multisetosus			I				I	
Coelotanypus spp.		I		I		I		
Procladius spp.		I		D				
Corbicula flumenia		I	I	I		I		

Source: Newling and Landin (1985).
* HD = Habitat development site; DS = Ducking Stool site.
** I = increase; D = decrease.

out. Shallow-water habitat remained along the transect lines. By contrast, emergent marsh habitat on the reference areas remained relatively stable along transect lines. Those comparisons that could be made showed a decline in all parameters of vegetation on WP in most quadrats compared with the reference areas.

161. At the present time, the WP site has broken into two smaller islands, each with different types of vegetation. The first of the two islands includes part of the original WP field site that was attached in 1974 along its eastern boundary to a very small, already existing dredged material island. The woody vegetation on this existing island has survived as it was prior to site construction over 13 years ago. The second of the two islands consists primarily of only herbaceous wetland plants, growing on a substrate consisting primarily of eroded dike and small remnants of the remaining marsh. Woody vegetation has not colonized this portion of the dredged material site, and it is still subject to erosion. The area between the two islands consists of shallow-water intertidal habitat and mud flats and isolated clumps of emergent pickerelweed.

162. Wildlife. More wildlife species diversity and actual numbers were observed at WP at all times after site construction than at any of the reference sites (Boesch et al. 1978, Newling and Landin 1985). This higher use occurred even with the two smaller islands and shallow-water habitat by shorebirds, waterfowl, and waterbirds. These results were expected, since WP was a new, rapidly evolving island that offered a variety of feeding areas and cover for birds and mammals. By 1984, mammal and some bird species were gradually decreasing because of the washout and subsidence of much of the upland/emergent marsh area on the island, but increased use by wading birds and ducks feeding in shallows has been noted.

Long-Range Plans

163. Norfolk District dredges the channel by the WP site on a regular basis and is considering placing maintenance dredged material behind the dike remnants of WP for marsh nourishment and partial restoration of this field site. When this occurs, long-term monitoring will also be a part of the overall effort to document movement of sediment and habitat development that occurs as a result of the placement operations.

Summary

164. Although the WP site has experienced problems with erosion and subsidence since its construction in 1974, it has been tremendously beneficial to the CE and successful in a number of ways. The site has developed into a highly productive, rapidly evolving freshwater marsh that has survived intact for over 9 years in a high-volume tidal river with strong spring floods, and it is diminishing in emergent vegetation but increasing in shallow-water fisheries habitat. The WP site has provided a demonstration site for use in testing wetland development techniques on dredged material. It has provided a basis for comparison of natural wetlands and man-made wetlands, and it has generated large amounts of quantitative data published in permanently available government documents that can be used in planning future wetland habitat development projects, especially those involving fine-grained dredged material. Further, it has provided a highly productive habitat for a diversity of wildlife and aquatic species.

165. In lessons learned, if woody plant species had been planted on the sand dike of the island initially, similar to those species found on nearby naturally colonized dredged material islands, the dike at WP may have stabilized and continued to protect the wetland interior. The placement of additional maintenance dredged material either initially or during a later dredging cycle behind the WP dike would also have helped stabilize the site and nourish the existing wetland. Wetland development in a dynamic river system such as the James should be undertaken with careful planning and with alternative management plans.

PART VIII: BUTTERMILK SOUND, ALTAMAHA RIVER, GEORGIA

Background

166. The Buttermilk Sound (BS) habitat development site is located on a 3-ha sandy dredged material island at the confluence of the Altamaha River and the Atlantic Intracoastal Waterway (AIWW), in Buttermilk Sound, Georgia (Figure 21). The island was built 7 to 10 years before the DRMP began and had remained a high unvegetated sand mound until the BS study. Most of the surrounding area was very dense intertidal saltmarsh with occasional high islands that are remnants from past dredging operations and old rice plantation dikes. These marshes were flooded twice daily by a 2-m tide that cut small tidal creeks throughout the area (Cole 1978).

167. Old marsh soils in the BS area were clay. However, newer and higher marshes were overlain with silty sand, and most of the material dredged from the AIWW was very sandy. The predominant vegetation throughout the area was smooth cordgrass, followed by big cordgrass, black needlerush, sea oxeye, saltgrass, saltmeadow cordgrass, wild rice, and marsh elder. Salinity in the area is fresh to brackish, and water quality was more influenced by the river than by the tides and the Altantic Ocean.

168. The BS site was chosen for study during the DMRP because it was representative of a South Atlantic sandy disposal site in a salt marsh. Objectives of the long-term study were to: (a) restore the sand mound to a intertidal marsh habitat; (b) document changes in the field site over time; (c) demonstrate that a stable marsh could be created using dredged material in the South Atlantic region, and (d) test various marsh plant species to determine which propagules, fertilizer treatments, and planting densities were more conducive to optimum marsh establishment in sandy soil.

169. Engineering and grading of the BS site were coordinated and carried out by the Savannah District. The University of Georgia conducted predisposal and postdisposal data collection through 1978 under contract to WES. Long-term monitoring through 1986 was conducted by the Environmental Laboratory (EL) at WES. Early phase (1974-1978) data were detailed in Hardisky and Reimold (1977); Reimold and Linthurst (1977); Cole (1978); and Reimold, Hardisky, and Adams (1978). Midphase data (1979-1982) were published in Newling and Landin (1985).

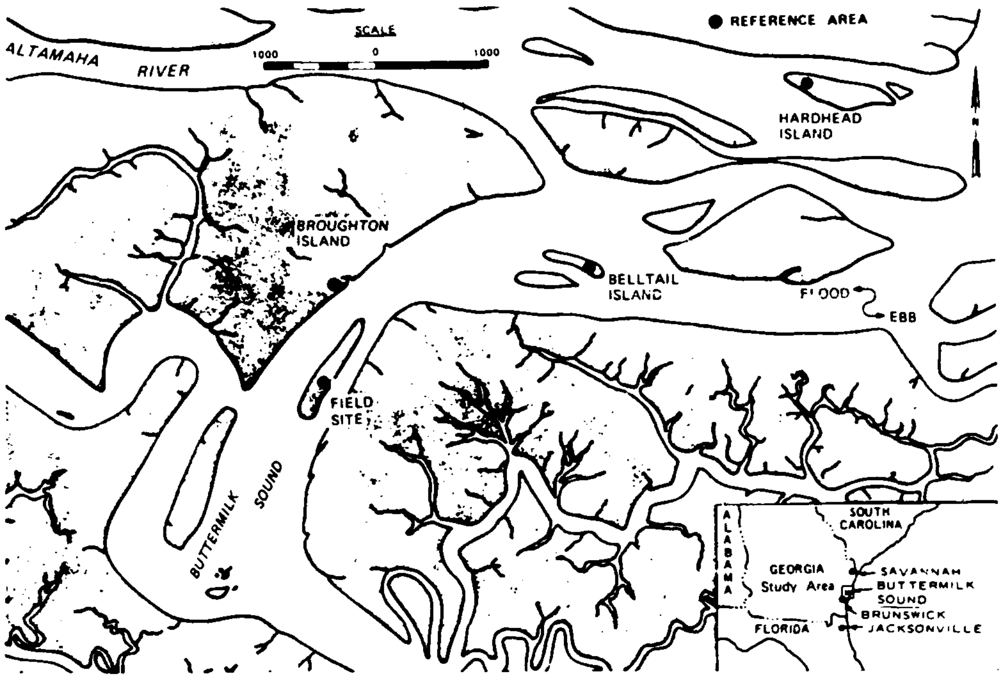

Figure 21. The BS field site in the Altamaha River near Brunswick, GA

Figure 22. The BS field site showing the revegetated portion of the island that was graded and planted. The lighter area is the original sand mound that was not changed in elevation

Site Development

1974-1978

170. Approximately half of the sand mound at BS was graded with a gentle slope to an intertidal elevation. Dredged material soil and soil water were analyzed within selected test plots from the lowest to the highest elevations within the planted marsh. Analyses were conducted for 11 micronutrients, organic matter, pH, Eh, extractable and total phosphorus, nitrite, ammonium nitrate, total dissolved oxygen, total nitrogen, and cation exchange capacity. Detailed results of these analyses are given in Reimold, Hardisky, and Adams (1978).

171. The site was laid out in a detailed experimental design (Cole 1978), which tested combinations of seven plant species, five fertilizer levels, and two types of plant propagules. It was planted in June 1975, with additional plantings of smooth cordgrass made in May 1976. Plant species tested were sea oxeye, saltgrass, marsh elder, black needlerush, smooth cordgrass, big cordgrass, and saltmeadow cordgrass; either seeds or sprigs of each were used in replicated experimental plots. A total of 80 test plots were established, including controls (no treatment). All plant materials, including seeds, were collected from nearby donor marshes. Plant survival data were published in Cole (1978) and Reimold, Hardisky, and Adams (1978) and are summarized below.

172. Marsh plant survival in the test plots appeared to be dependent on elevation and tidal inundation. Only smooth cordgrass sprigs initially survived at the lowest elevation. Some of all seven species survived at the midzone elevation. While more of each species survived in the high marsh zone, only saltmeadow cordgrass grew and expanded from the test plots rapidly. Saltmeadow cordgrass and smooth cordgrass comprised approximately 50 percent of the total aboveground and belowground biomass in the test plots. Invasion by 42 plant species occurred from 1975 through 1978 in the high marsh zone. The most common invaders were water hemp, panic grass, crabgrass, and marsh fleabane.

173. The five levels of fertilizer, ranging from 0 to 244 g/sq m, were found to have virtually no effect on planted species regardless of the type of propagule or the elevation in which the species was planted. Soil nutrient levels increased during early phase studies, but the concentrations at that

time remained below those of a nearby natural marsh. By 1978, the cordgrass had become dense enough that it was trapping significant quantities of fine-grained silt, which enhanced the nutrient level of the test plots. This process continued throughout the entire study (through 1986) until long-term monitoring was completed.

174. Reimold, Hardisky, and Adams (1978) made extensive wildlife and aquatic surveys before site development and through 1978 at both BS and at nearby marshes. These data are summarized as follows. By 1978, three species of crabs were found at BS, with fiddler crabs abundant on the site in the cordgrass. Nineteen species of fish and shrimp were collected by seining and trawling at the BS site and in Duplin estuary (Table 21). The most abundant species found were anchovies, white shrimp, and grass shrimp. In general inventories of the site and nearby marshes, alligators, diamondback terrapins, banded watersnakes, marsh rice rats, raccoons, and muskrats were the most common animals encountered.

175. Bird use of the site was not noticeably affected through 1978, since only half the mound had been graded and planted as marsh. A large number of gulls, terns, skimmers, and oystercatchers continued to use the high sand mound and shoreline for nesting and roosting. By the end of the DMRP study in 1978, clapper rails and other marsh birds were using the planted marsh. Extensive ground-level and aerial photographs were taken during this phase of the study, with aerial photographs taken again in 1979 to further document changes in the BS island site.

<u>1979-1982</u>

176. Following completion of the DMRP studies, low-level monitoring was conducted at BS and at three selected reference marshes in the vicinity, Broughton Island, Belltail Island, and Hardhead Island (Figure 21). However, in 1979, more extensive data collection was carried out under contract with the Georgia Department of Natural Resources* (Hardisky and Reimold 1979), and

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* M. A. Hardisky and R. J. Reimold, 1979a, "Buttermilk Sound Marsh Habitat Development Site, Glynn County, GA, 1978," Unpublished Technical Report prepared for the WES, Vicksburg, MS.
M. A. Hardisky and R. J. Reimold, 1979b, "Edaphic and Vegetational Factors Contributing to Macrophytic Biomass Production in Man-Made and Natural Marsh Areas," Unpublished Technical Report prepared for the WES, Vicksburg, MS.

Table 21

Numbers of Aquatic Species Captured by Trawl and Seine at BS

	Trawl				Seine	
	1976		1977		1976	1977
Species	BS	DE*	BS	DE	BS	BS
White shrimp	85	181	364	6	13	82
Common anchovy	27	134	31	49	0	4
Atlantic croaker	27	17	31	0	0	0
White catfish	10	0	21	0	0	0
Stardrum	9	69	12	3	0	0
Spot	9	13	38	2	1	1
Hogchoker	8	1	1	0	0	0
Weakfish	8	28	24	0	0	1
Atlantic herring	3	0	4	1	1	0
Atlantic menhaden	3	4	5	1	1	53
Striped mullet	2	0	1	0	253	139
Brown shrimp	0	21	0	0	0	0
Atlantic bumper	0	25	0	3	0	0
Squid	0	11	0	4	0	0
Grass shrimp	0	0	10	6	2,714	2,136
Atlantic silversides	0	0	0	3	42	19
Atlantic thread herring	0	0	0	0	0	74
Mummichog	0	0	0	0	40	15
Freshwater goby	0	0	0	0	26	3

* DE = Duplin Estuary, the earliest reference site in the Altamaha River for the BS field site and used for aquatic comparisons prior to 1978.

is summarized in Newling and Landin (1985) and briefly in the following paragraphs.

177. The BS site and the three reference sites were surveyed to be sure that the same elevational zones were being sampled, and they were divided into four zones between mean low water and the limit of spring tide inundation. Data were collected from three replicated plots at each site and at each elevation. Parameters included aboveground and belowground biomass (Table 22), stem density, percent cover, species composition, flowering heads, stem height for vegetation, and notation on crab burrow density in each plot.

178. In 1979, species composition differed from site to site. Although at all four sites smooth cordgrass was the only species present at the lowest zone, on BS in the upper zones, black needlerush, big cordgrass, smooth cordgrass, saltmeadow cordgrass, saltmarsh bulrush, and sea oxeye was all present. In contrast, only one of the three reference areas (Belltail Island) had as many as four of these species at higher elevations. Total biomass was found to be significantly greater at the BS site compared with the reference sites, although there were differences noted among the species. For example, smooth cordgrass was more productive than the natural sites, but big cordgrass was not. Saltmeadow cordgrass was similar at all sites. Saltmarsh bulrush was always found in mixed stands, if it was present at all. Plant variations that could not be accounted for by elevation or by soil type were noted at all four sites.

179. Belowground biomass was generally less at BS in 1979 than belowground biomass at the reference sites, although differences were also noted among reference sites. Other differences noted were that belowground biomass for smooth cordgrass at BS increased with increasing elevation and that big cordgrass belowground biomass at BS was only about half that at reference areas. Most roots tended to mass nearer the surface zone in the newer marsh (BS) than in the three older marshes. Differences in root masses and location of roots at various depths in the soil were attributed to soil types (sand versus clay). This difference in soil texture also affected roots at various elevational levels, since sandy soils tended to be better drained. The BS and Belltail Island sites were sandy, and root biomass decreased at lower elevations, while at Broughton Island and Hardhead Island with loamy/clay soils, root biomass remained consistent regardless of elevation.

Table 22

Summary of Biomass Measurement Listed in Descending Order by Elevational Zone from BS Habitat Development Site and Three Reference Marsh Sites During October 1979

			Species							
Zone	Area	Biomass Measurement	Black Needlerush	Big Cordgrass	Tall Form Smooth Cordgrass	Short Form Smooth Cordgrass	Saltmeadow Cordgrass	Saltmarsh Bulrush	Sea Oxeye	Total
4	Buttermilk Sound	Live	--	--	--	--	97 ± 49*	--	--	97
		Dead	--	--	--	--	133 ± 34	--	--	133
		Combined	--	--	--	--	230	--	--	230
		Belowground	--	--	--	--	1,696 ± 275	--	--	1,696
4	Broughton Island	Live	541 ± 52	652 ± 29	--	--	--	--	--	1,193
		Dead	204 ± 52	641 ± 261	--	--	--	--	--	845
		Combined	745	1,293 ±	--	--	--	--	--	2,038
		Belowground	8,057 ± 984	7,032 ± 2,535	--	--	--	--	--	15,099
4	Belltail Island	Live	200 ± 67	--	--	55 ± 9	--	--	--	255
		Dead	206 ± 18	--	--	163 ± 29	--	--	--	369
		Combined	406	--	--	218	--	--	--	624
		Belowground	2,222 ± 760	--	--	1,473 ± 307	--	--	--	3,965
4	Hardhead Island	Live	276 ± 59	421 ± 114	--	--	--	--	--	697
		Dead	163 ± 42	661 ± 36	--	--	--	--	--	824
		Combined	439	1,082	--	--	--	--	--	1,521
		Belowground	10,679 ± 430	8,577 ± 3,442	--	--	--	--	--	19,256
3	Buttermilk Sound	Live	240 ± 10	158 ± 44	445 ± 80	--	136 ± 51	82 ± 23	662 ± 309	1,723
		Dead	63 ± 12	454 ± 45	179 ± 39	--	132 ± 13	334 ± 122	0	753
		Combined	303	612	624	--	268	416	662	2,885
		Belowground	1,537 ± 167	3,337 ± 972	4,659 ± 812	--	1,728 ± 171	3,098 ± 1,284	725 ± 428	15,084
3	Broughton Island	Live	--	--	429 ± 260	775 ± 118	--	--	--	429
		Dead	--	--	155 ± 32	537 ± 61	--	--	--	155
		Combined	--	--	584	1,312	--	--	--	584
		Belowground	--	--	3,695 ± 339	8,975 ± 2,220	--	--	--	3,695
3	Belltail Island	Live	--	296 ± 44	369 ± 34	--	--	12 ± 4	--	1,452
		Dead	--	918 ± 175	127 ± 59	--	--	206 ± 74	--	1,788
		Combined	--	1,214	496	--	--	218	--	3,240
		Belowground	--	9,214 ± 1,978	2,636 ± 387	--	--	5,670 ± 1,229	--	26,495
3	Hardhead Island	Live	--	--	--	--	--	--	--	
		Dead	--	--	--	--	--	--	--	
		Combined	--	--	--	--	--	--	--	
		Belowground	--	--	--	--	--	--	--	
2	Buttermilk Sound	Live	--	--	723 ± 201		--	--	--	723
		Dead	--	--	114 ± 14		--	--	--	114
		Combined	--	--	837		--	--	--	837
		Belowground	--	--	1,290 ± 17		--	--	--	1,290

Note: All values are grams dry weight per square metre.
Source: From Newling and Landin (1985); after Hardisky and Reimold (1979a) and 1979b), op. cit.
* Values include the mean ± 1 standard error (n = 3).

180. By 1982, little evidence remained of the individual test plots planted in 1975. The BS site more closely resembled the reference sites in that the lowest elevational zone was mostly unvegetated mud flat. The upper two zones sampled by Hardisky and Reimold* were indistinguishable from the reference marshes. At that time, percent cover, stem height, and flowering heads were equal to that of the reference marshes, while stem density was slightly less at BS than at the reference marshes.

181. Vegetation was so dense that it was very difficult to conduct sampling at all four sites. The very heavy vegetation in Zones 2 and 3 at BS were directly attributable to the cordgrass trapping silt over the sand dredged material and apparently enriching the marsh. This silt layer ranged from 5 to over 25 cm across the site. Hard-packed silt layers appeared to be present at Belltail Island (the other originally sandy site) as well. In 1982, mean percent cover ranged from 89 percent at BS to 66 percent at Hardhead Island. Smooth cordgrass stem density ranged from 79 at BS to 53.5 at Hardhead. Differences in species composition and in zonation were still evident at all four sites, with the greatest species diversity occurring at BS and at Hardhead Island.

182. Very limited wildlife observations were made at the BS site through 1981, with the primary emphasis on vegetation, soils, fish, and benthos. General wildlife observations were made from 1982 through the end of the study, with an inventory of use presented in Table 23. It had already been noted that wildlife species diversity was much greater at BS than at the reference sites because of the differences in habitat and plant diversity presented by the elevational changes (from low marsh to sandy mound) at BS. This sand mound was used for nesting by least terns each year and for resting by hundreds of seabirds that fed in the river and along the AIWW. Considerable use of the marsh was noted in 1982 and later years by yellow-crowned night-herons, great blue herons, and other herons and egrets; by nesting clapper rails and marsh wrens; and by bitterns and other marsh birds. Each year of observation also indicated common use of BS by white-tailed deer, raccoon, muskrat, and swamp rabbits.

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* Hardisky and Reimold, 1979a, op. cit.

Table 23

Wildlife Species Observed at BS Field Site, 1980-1986

Birds	Others
American bittern 2*	American alligator 3
American oystercatcher 1,3	Banded watersnake 3
Bank swallow 1,2,3	Blue crab 2,3
Barn swallow 1,2,3	Diamondback terrapin 1,3
Belted kingfisher 3	Fiddler crabs (3 spp.) 2,3
Black-bellied plover 3	Marsh rice rat 2
Black-crowned night-heron 2,3	Muskrat 2,3
Black skimmer 1,3	Raccoon 2,3
Boat-tailed grackle 1	Swamp rabbit 1,2,3
Caspian tern 3	White-tailed deer 1,2,3
Clapper rail 2,3	
American crow 1	
Common grackle 1	
Common tern 3	
Forster's tern 3	
Fish crow 1,3	
Great black-backed gull 3	
Great blue heron 2,3	
Great egret 2,3	
Green-backed heron 1,3	
Herring gull 3	
Laughing gull 3	
Least sandpiper 3	
Least tern 3	
Lesser yellowlegs 3	
Little blue heron 2,3	
Marsh wren 2	
Mourning dove 1	
Northern harrier 1	
Osprey 3	
Pied-billed grebe 3	
Redhead 3	
Red-winged blackbird 1,2,3	
Ring-billed gull 3	
Royal tern 1,3	
Ruddy turnstone 3	
Sandwich tern 1,3	
Semipalmated sandpiper 3	
Sharp-tailed sparrow 2	
Short-billed dowitcher 3	
Short-eared owl 1	
Snowy egret 2,3	
Virginia rail 2,3	
Western sandpiper 3	
Willet 1,3	
Yellow-crowned night-heron 2,3	
Yellow rail 2,3	

* 1 = island sand mound; 2 = planted marsh; 3 = shoreline.

1983-1986

183. Low-level vegetation monitoring efforts at BS were conducted in 1983, 1984, and 1986, with more extensive transect sampling in Zones 2 and 3 in 1985. At that time, species composition, stem density, stem height, flowering stems, and percent cover were measured. No biomass samples were taken. These site visits were primarily to note any physical and environmental changes on BS and the reference sites, since the planted marsh was relatively stable and unchanged from previous samplings. Vegetation data collected (Table 24) show a continued larger number of plant species within the planted marsh than in the reference areas. Sea oxeye was marginally present only on the planted marsh (and did not coincide with transects), and it is assumed that it would never have been present at the BS site had it not been planted. Black needlerush was gone from all sites, and the predominant vegetation by far was smooth cordgrass and big cordgrass in the lower elevational zones.

184. By 1986, no trace of the original test plots could be found. The intertidal marsh plants (primarily smooth cordgrass and big cordgrass) at the BS site and at the reference sites were so dense and so tall that transect stakes could not be relocated from year to year. Fines trapped by the cordgrass were also influencing the sand mound on the island, and it was becoming more and more vegetated with grasses and forbs such as camphorweed, marsh fleabane, crabgrass, nightshade, and other common invader species (Table 25). Vegetation on the mound was becoming dense enough to preclude nesting by least terns, and no signs of nests were found in 1983-1986. However, gulls, terns, skimmers, and a variety of shorebirds continued to rest on the mud flats and shorelines of the BS site, while herons and egrets fed in its shallows. Nesting use of the planted marsh by clapper rails, marsh wrens, and American bitterns also continued at BS. Resident and occasional use by raccoons, muskrats, white-tailed deer, and swamp rabbits was observed (Table 23).

Long-Range Plans

185. Savannah District has been considering placing maintenance dredged material on the BS site again, adjacent to the planted marsh. Since this material would be primarily sandy, the same techniques for stabilizing and revegetating the material developed during the BS study would be applicable to

Table 24

Summary of Data Collected at BS Field Site and Reference Areas in 1982 and 1985

Site	Species	Stem/sq m Density		Stem Height, cm		Freq. of Occurrence %		Flowering Stems/sq m	
		1982	1985	1982	1985	1982	1985	1982	1985
BS	Big cordgrass	8.8	10.4	283.3	305.6	50.0	50.0	2.6	4.5
	Saltmarsh bulrush	10.0	7.5	150.8	147.2	50.0	50.5	0.5	0.0
	Smooth cordgrass	79.0	82.6	131.5	127.3	100.0	100.0	0.0	2.0
	Softstem bulrush	7.0	3.5	179.0	170.8	25.0	50.0	1.2	3.0
	Mean % cover: 1982 = 88.8; 1985 = 95.0								
BI*	Big cordgrass	40.0	32.7	268.9	255.1	100.0	100.0	5.5	4.7
	Saltmarsh bulrush	--	3.4	--	151.4	0.0	25.0	--	0.0
	Mudwort	365.0	400.0	2.0	2.0	50.0	75.0	0.0	0.0
	Smooth cordgrass	55.6	63.9	128.2	123.7	75.0	75.0	0.0	1.0
	Mean % cover: 1982 = 76.2; 1985 = 8.0								
BLI*	Saltmarsh aster	37.0	23.6	50.8	53.4	50.0	75.0	0.0	0.0
	Big cordgrass	1.0	--	243.5	--	25.0	0.0	1.0	--
	Seaside goldenrod	0.5	2.0	78.0	80.0	25.0	25.0	0.0	0.0
	Smooth cordgrass	53.5	61.4	134.8	130.9	100.0	100.0	0.0	3.0
	Softstem bulrush	285.0	267.2	126.7	136.3	100.0	100.0	8.0	5.0
	Mean % cover: 1982 = 66.2; 1985 = 63.8								
HI*	Big cordgrass	N/A**	3.5	N/A	256.8	N/A	50.0	N/A	1.0
	Smooth cordgrass	N/A	93.2	N/A	137.9	N/A	100.0	N/A	2.0
	Softstem bulrush	N/A	15.4	N/A	125.2	N/A	50.0	N/A	3.0
	Mean % cover: 1982 = 63.7; 1985 = 60.1								

* BI = Broughton Island reference site.
BLI = Belltail Island reference site.
HI = Hardhead Island reference site (not sampled in 1982).
** N/A = not available for these species.

Table 25

Plant Species Recorded at BS Field Site, 1974-1986

Species	Habitat and Remarks
American three-square	Middle and high marsh zones
Bahia grass	On sandy mound
Beach morning glory	On sandy mound
Big cordgrass	In middle and upper marsh zones
Bindweed	In upper marsh zones
Blue curls	On sandy mound
Broadleaf cattail	In middle and upper marsh zones
Cabbage palm	On fringe of sandy mound
Camphorweed	In high marsh zone
Common Bermuda grass	On sandy mound
Common elder	On fringes of sandy mound
Common greenbriar	In trees on fringes of sandy mound
Cowpea	On sandy mound
Crabgrass	In high marsh zone and sandy mound
Curly-leaf dock	In high marsh zone and sandy mound
Deer pea	In high marsh zone and sandy mound
Densely-flowered smartweed	In high marsh zone
Dodder	In shrubs on fringes of mound
Dog fennel	On sandy mound
Drummond sesbania	On sandy mound fringes
Eastern red cedar	On sandy mound fringes
Groundsel tree	In high marsh zone
Marsh elder	In high marsh zone
Marsh fleabane	In middle and upper marsh zone
Nightshade	On sandy mound
Nodding smartweed	In high marsh zone
Ogeechee plum	On sandy mound fringes
Peppergrass	On sandy mound
Pickerelweed	In high marsh zone
Pokeweed	On sandy mound
Poor-joe	On sandy mound
Rice cutgrass	In middle and high marsh zones
Rose mallow	In high marsh zone
Saltgrass	In high marsh and on sandy mound
Saltmarsh aster	In middle marsh zone
Saltmarsh bulrush	In middle and high marsh zones
Saltmarsh cattail	In middle and high marsh zones
Saltmarsh fleabane	In middle and high marsh zones
Saltmarsh morning glory	In high marsh zone
Saltmeadow cordgrass	In high marsh zone
Sandspur	On sandy mound
Sea oxeye	In high marsh zone
Seashore mallow	In middle and high marsh zones
Seaside goldenrod	On sandy mound
Smooth cordgrass	In lower and middle marsh zones
Softstem bulrush	In middle marsh zone

(Continued)

Table 25 (Concluded)

Species	Habitat and Remarks
Southern wild rice	On island vegetated fringes
Switchgrass	On island vegetated fringes
Water hemp	On sandy mound and high marsh
Wax myrtle	On sandy mound fringes
White thoroughwort	On sandy mound
Wild rice	Mixed with cordgrass in lower zone
Wisteria	In trees on mound fringes
Yerba	On sandy mound
Yucca	On sandy mound

the new deposit of dredged material. Based on this study, there is little doubt that saltmarsh can be reestablished on dredged material in BS. However, the habitat diversity aspect of BS has not been fully explored. It offers a beneficial use option to more saltmarsh, an abundance of which already occurs in the vicinity of BS. Creation of a site with more diverse site habitat incorporating both marsh fringes and bare ground-nesting sites for terns would present a greater opportunity for diversity and abundance of wildlife using the dredged material.

Summary

186. The BS site was a high, sandy dredged material mound prior to site development in 1975. Since that time, it became a highly productive intertidal marsh that provided greater plant and wildlife diversity than any of the surrounding areas, including the three reference marshes selected for comparison purposes. Cordgrasses on the BS site formed a dense, lush mass of vegetation very similar to surrounding marshes, with plants reaching heights of 3 m or more. Remnant populations of planted species black needlerush, sea oxeye, marsh elder, and saltgrass remained, but the predominant vegetation on planted portions of BS was smooth cordgrass and big cordgrass in lower intertidal zones, with saltmeadow cordgrass in the highest marsh/upland zone. The BS site visually was identical to the marshes in the vicinity.

PART IX: APALACHICOLA BAY, APALACHICOLA, FLORIDA

Background

187. Apalachicola Bay (AB) habitat development field site is located on Drake Wilson Island in Apalachicola Bay, Florida (Figure 23). This project location was selected because it represented a northeast gulf coast intertidal saline island site within a shallow bay and was subjected to long wind fetches that could cause erosion of a man-made marsh.

188. All construction, surveying, and dredging work was done by the Mobile District. Early field site research was conducted by WES and by a contract with Florida A&M University. Mid- and late-phase research was conducted solely by WES. The wetland site was planted by WES, and the upland portions of the island were planted by Mobile District.

189. Apalachicola Bay is one of the most productive and least contaminated estuaries in the United States. Rainfall averages 143 cm annually, and summers are hot and humid. Average annual temperatures are 20.4° C, with an average of only 5 days of below freezing weather. The tidal range is approximately 0.5 m in the bay and is heavily influenced by wind. The salinity of the bay ranges from brackish to sea strength, depending upon freshwater inflow from rivers and streams.

190. The bay supports considerable commercial fishing for oysters, blue crabs, and shrimp, and the local Apalachicola economy is based on this resource. Sport fishing in the bay for seatrout, redfish, sheepshead, whiting, and flounder also contributes to the local economy. Primary wildlife use in the vicinity of the field site is feeding and resting waterbirds and shorebirds. Several heron and egret species, brown pelicans, laughing and herring gulls, several species of terns, and black skimmers frequent the area. Raccoons, muskrats, and other small mammals also naturally occur in the vicinity.

191. Drake Wilson Island is one of two enlarged islands developed to hold dredged material from Two-Mile Channel (Figure 24); it was constructed by building triangular-shaped dikes of sandy clay dredged material, which were then filled with sandy dredged material from the channel. A weir was installed in the island dike on the western side of the channel prior to wetland development to allow intertidal exchange. A capping layer of

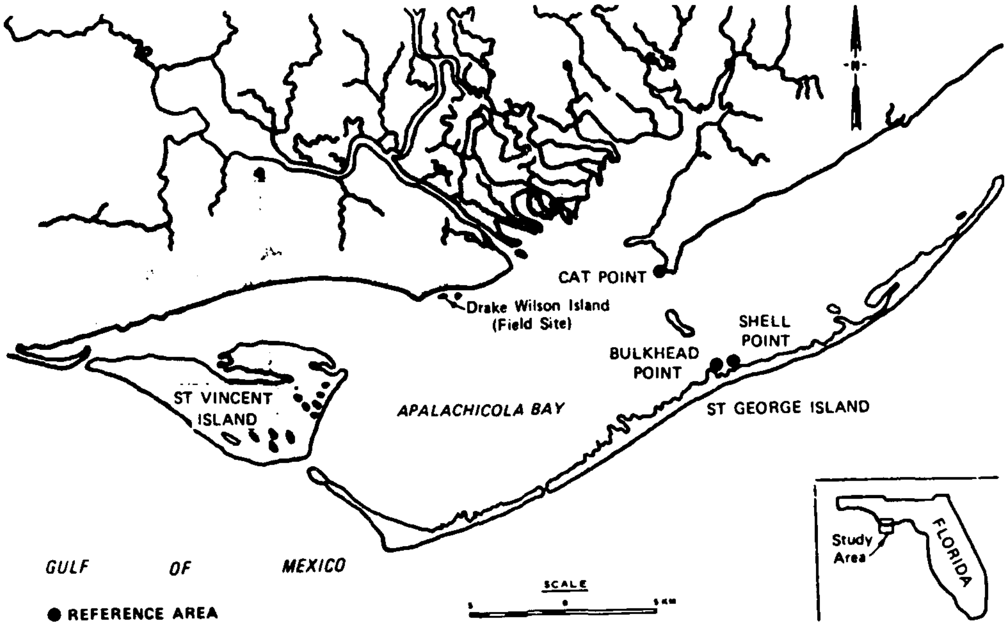

Figure 23. The AB field site at Apalachicola, FL

Figure 24. The AB field site, showing the marsh beginning to develop inside the dike. Note the weir in the lower righthand corner

fine-grained silty dredged material was pumped into the disposal area over the older coarse-grained sandy dredged material prior to planting of the site.

Site Development

1975-1978

192. During the DMRP, the AB field site was designed to test the feasibility of growing wetland plants on both fine- and coarse-grained dredged material in a saline environment. In addition, various spacings between plants were tested to determine optimum spacing for site stabilization under the wave and tidal energy conditions of AB and to be able to predict optimal spacings for similar wetland development sites.

193. After site preparation (dredged material placement and weir construction), transplants of smooth cordgrass and saltmeadow cordgrass were planted in silt and sand, respectively, in July 1976. These transplants came from nearby donor marshes on St. Vincent's Island (Figure 23) and were planted primarily by hand. Mechanical planting was also attempted using a RUC-drawn sled. However, because of difficulty in working from the sled, future use of this technique was not recommended for planting in fine-grained dredged material.

194. Although the field site topography was nearly flat after hydraulic placement of the dredged material, a very slight slope towards the bay aided in intertidal exchange. Smooth cordgrass transplants were planted in silt at the lowest intertidal range and at five spacings: 0.3, 0.6, 0.9, 1.8, and 2.7 m within separate experimental plots. All transplants in experimental plots were handled similarly and were planted at the same depth of approximately 10 cm. Control plots were left unplanted.

195. Transplants of saltmeadow cordgrass were planted in sand at the higher intertidal range, at similar depths, and at four spacings: 0.3, 0.9, 1.8, and 2.7 m. Control plots consisted of the bare areas between the four experimental plots that were planted.

196. All plantings were monitored for percent survival, percent cover, seed production, stem density, biomass, and numbers of new shoots. Early vegetation data from this field site have already been published in detail in Kruczynski, Huffman, and Vincent (1978); Newling, Landin, and Parris (1984);

and Newling and Landin (1985). Field site findings are summarized in the following paragraphs.

197. By September 1977, all smooth cordgrass plots with 0.9-m or less spacings had already reached 100-percent vegetation cover. For example, stem density for 0.3-, 0.6-, and 0.9-m spacing, respectively, increased from 14, 6, and 6 stems/sq m in December 1976 (5 months after planting) to 180, 166, and 134 stems/sq m by September 1977.

198. However, at the 1.8- and 2.7-m spacings, smooth cordgrass transplant results were very poor. Although good growth was observed around surviving transplants, most of the original plants were washed out from tidal action as the result of the wider spacing, loose consolidation of the substrate at planting, and proximity to the weir where tidal effects were greatest. By 1978, only about 10 percent of the 1.8- and 2.7-m spaced plots were covered with smooth cordgrass.

199. In the saltmeadow cordgrass plots, approximately 75-percent cover was obtained in the 0.3- and 0.6-m spacings within 1 year (by September 1977), and 100-percent cover was achieved by September 1978. The more densely spaced plantings provided faster cover and more overall biomass. However, the more widely spaced plants experienced much greater growth per transplant. For example, in April 1977, closely spaced saltmeadow cordgrass transplants (0.3- and 0.6-m) averaged less than 100 stems/plant, while more widely spaced transplants (1.8- and 2.7-m) averaged more than 600 stems/plant. In addition, the more vigorous and darker green stems were observed on the widely spaced transplants of saltmeadow cordgrass.

200. In both smooth cordgrass and saltmeadow cordgrass, approximately 50 percent of the transplants were flowering in September 1977, and 100 percent were flowering in September 1978.

201. Both species planted completely covered test plots at 0.9-m spacing or less within two growing seasons. More widely spaced plots over time fared poorly through washout of smooth cordgrass transplants and competition of invading species in saltmeadow cordgrass transplants. Therefore, closer spacing of about 0.75 to 1.0 m appears to be best for optimum vegetation establishment under site and dredged material conditions such as those found at AB.

1979-1982

202. One of the primary events during this stage of site development was the selection of three nearby natural wetland reference areas to use for comparison to AB. These were Bulkhead Point, Shell Point, and Cat Point (Figure 23), and while they were similar to the AB site, none of them was located on an island. Vegetation and general observation data were collected at all four locations in random quadrats along line transects across the wetland areas (Newling and Landin 1985). An important observation was that from 1979 through the completion of the AB study, the three older (ages unknown) reference sites were relatively stable in appearance and in the makeup of plant and animal communities throughout the remaining study, while the AB site continued to evolve from a marsh in an early successional stage to a complex plant and animal island community.

203. The silty dredged material used as a cap for the sand material in the intertidal zone remained basically unconsolidated throughout the study and would not support the weight of an adult human. However, it did support the dense growth of smooth cordgrass that dominated the lower elevations of AB.

204. Another major event that took place between AB construction and midphase of its development included changes in the dike. By 1982, the dike had been greatly modified by wave action, and the weir was no longer functioning. Intertidal flow was provided by two natural breaches in the dike, which continued to widen with time from storm tides frequently overtopping the dike.

205. The interior of the AB wetland had also changed appreciably since site construction. From a patchwork of experimental plots and open-water areas in the 1970s, by 1982 the site was totally covered with a stand of smooth cordgrass with only one small remaining pond that had been the original location of the disposal pipe and was also the unplanted control area. In the transition zone between mean low water and mean high water, between the planted stands of smooth cordgrass and saltmeadow cordgrass, stands of saltmarsh bulrush and dense areas of saltgrass had colonized naturally.

206. By 1982, the original saltmeadow cordgrass plantings were no longer monotypic stands, but had been invaded by bahia grass, beardgrass, blazing star, brome grass, club moss, coarse rush, dog fennel, groundsel tree, marsh loosestrife, pennywort, pilewort, and royal fern. In general, saltmeadow cordgrass was still the dominant species, depending upon the original

plant spacings. For example, in the 0.3-m plot, there was a 75- to 100-percent saltmeadow cordgrass cover. The species cover trended downward with spacing until at the 2.7-m spacing, saltmeadow cordgrass made up only 10 percent of the cover (Newling and Landin 1985). The early observation by Kruczynski, Huffman, and Vincent (1978) that wider spacings of saltmeadow cordgrass resulted in more biomass per transplant did not hold true over the long-term, as the saltmeadow cordgrass received too much competition from invading species to predominate.

1983-1987

207. During this phase of site development, there was much less physical and environmental change of the site. Smooth cordgrass continued to dominate the intertidal area, with mixed stands on the fringes of saltmarsh bulrush, cattail, and saltgrass. The open-water pond remained intact without changing its size. The dike breached wider, but the fringes of the established marsh were holding against the erosive forces of wind and wave action. Saltmeadow cordgrass occurred densely in the old 0.3- and 0.6-m spacing plots, but was all but eradicated through competition from other species from within the 1.8- and 2.7-m spacing plots.

208. Table 26 reflects changes in stem density from 1977, 1982, and 1986 for smooth cordgrass, with 1982 and 1986 data compared with the three reference wetlands. Note that stem density was greater in 1977 when the marsh was new and vigorously growing (160.3) than in 1982 (137.8) when the marsh was only 5 years old, or in 1986 (130.4) after the marsh had reached 10 years of age. Stem height also follows a similarly downward trend, showing a mean of 108.4, 93.7, and 90.6 cm, respectively. Data from 1982 and 1986 compare favorably within the range of variability of that found at the three reference areas in stem density and stem height. Frequency of occurrence (100 percent across all sites) and percent cover are also very similar for all sites.

Plant invasion

209. The AB field site began as bare sand and silt (depending upon location within the site) in 1976, and the entire island complex had become vegetated by 1986. Within the planted wetland area, a total of 42 invading species had colonized by 1978 (Kruczynski, Huffman, and Vincent 1978). By 1982, an additional 17 species had invaded the wetland area (Newling and Landin 1985). In addition, in the upland portion of the island that had been bare prior to site development, 95 plant species were identified (Newling and

Table 26

Summary of Vegetation Data Collected at the AB Field Site and Reference Areas in 1977, 1982, and 1986

Species	Year	Stem/sq m Density	Stem Height cm	Freq. of Occurrence, %	No. Flowering Stems/sq m	Cover %
			Apalachicola Bay			
Smooth cordgrass	1977	160.3	108.4	100.0	0.0	55.8
	1982	137.8	93.7	100.0	4.0	73.0
	1986	130.4	90.6	100.0	9.0	88.0
Saltmarsh bulrush	1977	N/A	N/A	N/A	N/A	N/A
	1982	1.8	80.1	25.0	0.0	N/A
	1986	4.7	82.8	25.0	0.0	N/A
			Bulkhead Point*			
Smooth cordgrass	1977	N/A	N/A	N/A	N/A	N/A
	1982	83.5	79.2	100.0	0.0	49.0
	1986	79.3	80.6	100.0	2.0	54.4
			Shell Point*			
Smooth cordgrass	1977	N/A	N/A	N/A	N/A	N/A
	1982	190.0	52.3	100.0	0.0	75.0
	1986	172.4	58.3	100.0	0.0	70.0
			Cat Point*			
Smooth cordgrass	1977	N/A	N/A	N/A	N/A	N/A
	1982	161.0	111.4	100.0	0.0	89.0
	1986	146.3	99.6	100.0	3.0	75.0

* Three reference areas similar to the AB site were not located until 1980 and were not sampled quantitatively until 1982. Almost no high marsh zone at reference sites existed, and high marsh comparisons could not be made.

Landin 1985). All plant species found on AB since its construction are listed in Table 27. These included eight species that had been planted by the Mobile District in 1976 to help stabilize the sandy upland (cabbage palm (all dead by 1980), coastal sedge, beach panic grass, Virginia creeper, knotgrass, common reed, sand pine, and coastal dropseed). The pines and other tree species had reached a height of 3 to 6 m by 1986 and were providing cover and protection for the growth of other plant species.

210. Only 11 plant species were found on the fringes of the reference wetlands that were not found at AB. These were common greenbrier, glasswort, grape vine, live oak, foxtail grass, poison ivy, prickly pear cactus, sea lavender, sea oats, woolly croton, and yaupon, all considered primarily upland plants.

Wildlife and fish

211. No wildlife or fisheries data were collected for the AB site in its early days of development, as initially the only criteria considered important were those listed in paragraph 192. Beginning in 1979, general observation data of onsite and nearby wildlife use were collected (Newling and Landin 1985). Least terns and Caspian terns nested from 1979 through 1983 on the bare sand portions of the island before the sand became vegetated. Clapper rails and marsh wrens have been observed nesting in the low marsh each year, and red-winged blackbirds, northern mockingbirds, common grackles, and killdeer nested in the upland portion of the island.

212. A total of 39 bird species have been observed using the AB site during all seasons (Table 28), as well as cottontail rabbits, eastern moles, muskrats, opossums, and raccoons. The island is less than 50 m from the Apalachicola mainland and was frequently visited by community children who used parts of the upland portions as a playground (complete with handmade wooden fort and cave) and their pets. Ground-nesting or colony-nesting birds had limited nesting opportunities because of this intrusion, which occurred primarily during summer months. However, the interspersion of habitat on the island in relation to the three reference areas may account for the much heavier wildlife use at AB.

213. The most conspicuous use of the site was by great blue herons, tri-color herons, little blue herons, yellow-crowned night-herons, great egrets, snowy egrets, and brown pelicans that frequented the ponded area within the intertidal marsh and the shallow-water fringes of the dikes.

Table 27

Plant Species Recorded on AB Field Site, 1975-1986

American three-square 1*
Arrowheads 1
Bagpod 2
Bahia grass 1,2
Baldcypress 1
Barnyard grass 1,2
Beach panic grass 2
Big smartweed 1
Bitter panic grass 2
Black cherry 2
Black needlerush 1
Blazing star 1
Broadleaf cattail 1
Brome grass 1,2
Bushy beardgrass 1,2
Cabbage palm 1
Camphorweed fleabane 1,2
Centipede grass 2
Chufa 1,2
Climbing hempweed 2
Club moss 1
Coarse nutsedge 1,2
Coarse rush 1
Coastal dropseed 2
Coastal sedge 2
Common Bermuda grass 2
Common plantain 1,2
Common ragweed 2
Common reed 1,2
Crabgrass 2
Curly-leaf dock 2
Dallis grass 2
Dandelion 2
Deer pea 2
Dog fennel 1,2
European beachgrass 2
Fall panic grass 2
Fimbristylis 1,2
Fleabane 2
Globe nutsedge 1,2
Green ash 2
Ground pine 2
Groundsel tree 1,2
Knotgrass 2
Lead plant 2
Lichens 1,2
Loblolly pine 2
Longleaf pine 2
Marsh rose mallow 1
Mosses 1,2
Nutsedges (3 spp.) 1,2
Ogeechee plum 2
Onion 2
Palmetto 2
Panic grass 2
Pennywort 1
Pepper bush 2
Peppervine 2
Perennial saltmarsh aster 2
Pigweed 2
Pilewort 1
Plantain 1,2
Pokeweed 2
Red rattlebox 2
Rose mallow 1,2
Royal fern 1
Saltgrass 1,2
Saltmarsh bulrush 1
Saltmarsh cattail 1
Saltmarsh fleabane 1
Saltmarsh morning glory 1
Saltmarsh sand spurry 1
Saltmeadow cordgrass 1
Sand pine 2
Saw grass 1
Sea oxeye 1
Sea purslane 1
Seashore mallow 1,2
Seaside goldenrod 2
Sedges 1,2
Sensitive fern 2
Shortleaf pine 2
Sicklepod 2
Small white morning glory 2
Smooth cordgrass 1
Softstem bulrush 1
Southern dewberry 2
Spiderwort 2
Spikerush 1,2
Spiny sandspur 2
Spurge 2
St. Augustine grass 2
Swamp dock 1,2
Switchgrass 2
Virginia creeper 2
Water hemp 1
Marsh loosestrife 1,2
Water pennywort 1
Water smartweed 1
Wax myrtle 2
Yerba 2
Yucca 2
Marsh elder 1
Water hyssop 1

* 1 = growing in planted marsh; 2 = growing on island upland.

Table 28

Wildlife Observed on the AB Field Site, 1975-1986

American coot 3*	Little blue heron 1,3
American crow 1,2,3	Mallard 3
American oystercatcher 2,3	Marsh wren 1
American robin 2	Mourning dove 2
Ants (native) 2	Muskrat 1
Bank swallow 1,2	Northern flicker 2
Barn swallow 1,2	Northern harrier 1,2
Belted kingfisher 1	Northern mockingbird 2
Black-bellied plover 3	Northern rough-winged swallow 1,2
Black-crowned night-heron 1	Opossum 2
Black vulture 2	Purple martin 1,2
Blue crab 1,3	Raccoon 1,3
Blue-gray gnatcatcher 2	Red-tailed hawk 2
Blue jay 2	Red-winged blackbird 1,2,3
Boat-tailed grackle 2,3	Ring-billed gull 3
Brown-headed cowbird 2	Royal tern 2,3
Brown pelican 1,3	Ruby-throated hummingbird 2
Brown thrasher 2	Sanderling 3
Carolina chickadee 2	Sandwich tern 2,3
Caspian tern 1,3	Savannah sparrow 2
Cattle egret 3	Seaside sparrow 1
Common nighthawk 2	Semipalmated plover 3
Clapper rail 1	Sharp-tailed sparrow 1
Common grackle 2,3	Snowy egret 1,3
Common yellowthroat 1,2	Spotted sandpiper 1,3
Double-crested cormorant 3	Tri-color heron 1,3
Eastern cottontail 2	Western sandpiper 1,3
Eastern mole 2	Whimbrel 3
European starling 2	White ibis 1,3
Fiddler crabs (3 spp.) 1	White-throated sparrow 2
Field sparrow 2	Willet 3
Fire ants 2	Yellow-rumped warbler 2
Fish crow 3	Yellow-crowned night-heron 1,3
Gray catbird 2	
Great blue heron 1,3	
Great egret 1,3	
Greater yellowlegs 3	
Green-backed heron 1	
Gull-billed tern 3	
Hermit crab 3	
Herring gull 3	
House sparrow 2	
Killdeer 2,3	
Killifish 1	
Laughing gull 1,2,3	
Least sandpiper 3	
Least tern 2,3	

* 1 = planted marsh; 2 = island upland; 3 = shoreline.

Shorebirds and seabirds, primarily laughing gulls and several tern species, loafed along parts of the dikes that remained bare. Since the AB site was so close to the mainland, a number of "landbirds" also were commonly observed, including common crows, blue jays, robins, black vultures, red-tailed hawks, mockingbirds, yellow-rumped warblers, and several species of sparrows in winter and swallows during summer and migration.

214. In the intertidal marsh, abundant populations of fiddler and blue crabs have occurred since the marsh was first planted. Fiddler and blue crabs also were abundant in all three reference marshes. Killifishes and other small fishes have been observed in the open pond area and in the fringes of the marsh during high tide, but no quantitative data have been collected on this fish use. Because of manpower and budget constraints, no attempt to collect macroinvertebrate data within the AB site and reference marshes was made.

Summary

215. The AB field site has been considered stable for several years in spite of some continued moderate erosion near the old weir location. However, the smooth cordgrass appears to be holding the saltmarsh. The upland portion of the AB site, once entirely bare sand, now has plant cover in all locations. The young trees planted on the site, plus colonizing trees and other plants, have become large and now provide considerable wildlife habitat.

216. The techniques developed at the AB site of breaching a dike, and/or installing a weir for tidal exchange, and then planting the site for stability were demonstrated to be quite successful in both establishing the wetland on silty dredged material and in improving fish and other estuarine habitat through the formation of tidal channels and the tidal pond in the site. More care in stabilizing the weir in such wetland development efforts is necessary, since the AB site would have not been as successsful had not natural breaches occurred after weir failure that allowed intertidal flow.

PART X: BOLIVAR PENINSULA, GALVESTON BAY, TEXAS

Background

217. The Bolivar Peninsula (BP) field site is located on Goat Island in Galveston Bay, Texas, (Figure 25), adjacent to the Gulf Intracoastal Waterway (GIWW), which is maintained on a 3-year dredging cycle. Material from this channel is pumped over the crest of Goat Island and allowed to flow towards Galveston Bay, creating a series of fan-shaped sandy deposits of varying ages (Figure 26). Three of these deposits on the island have been studied and are grouped under the field site name, although they vary in age and the time in which study of these deposits began.

218. Bolivar Peninsula is at the eastern end of a long chain of barrier islands and inlets along the Texas and Mexican coasts and is connected to the mainland on its eastern end. Underlying soils are loamy clays, but almost all dredged material from the GIWW is sand that has drifted into the channel. Goat Island was created over 40 years ago when the GIWW channel was dug through BP, cutting off that portion of the peninsula and forming the island. A large herd of 300 to 350 feral goats live on the island and are selectively harvested once a year by a nearby landowner. Ranching, oil, and commercial and recreational fishing are the primary land and water uses adjacent to the BP site.

219. The BP site was selected for study during the DMRP because it was representative of a sandy, gulf coast unconfined disposal site that presented chronic revegetation problems. It also was intertidal, with a 42-km wind fetch across shallow Galveston Bay, which caused severe to moderate erosion along the BP shoreline.

220. The entire island was severely overgrazed and impacted by the goats, which had to be fenced out of the BP study site. Although six distinct and separate plant communities were identified on the island and each was dominated by either big bluestem, saltmeadow cordgrass, seashore dropseed, Drummond sesbania, lemon beebalm, and smooth cordgrass, almost no marsh existed on the island, especially in the intertidal zone.

221. The development of the BP site was a cooperative effort by several offices and groups, although it was funded entirely by the CE. Engineering, topographic work, soil and dredged material sampling and testing, and all

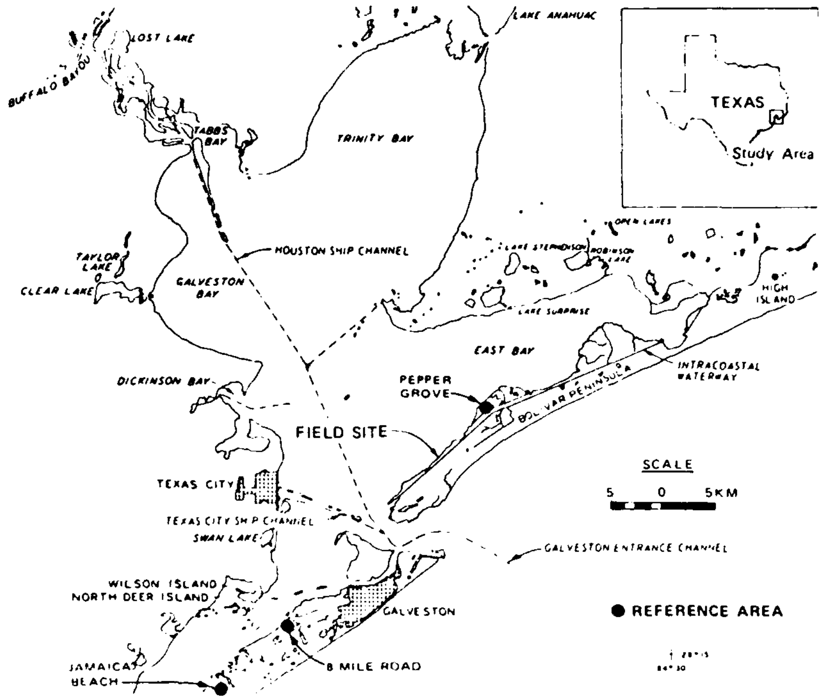

Figure 25. The BP field site in Galveston Bay, Texas

Figure 26. Initial fan-shaped sandy dredged material deposit that was graded, planted, and monitored at Bolivar Peninsula, Texas

construction and repair site activities were carried out by the Galveston District. An inventory and assessment of hydrology and water chemistry were completed by the US Geological Survey Office, and an inventory and assessment of aquatic biota in the early development phase was conducted by the NMFS.

222. The bulk of the research was conducted by Texas A&M University (TAMU) under contract to WES. The TAMU was responsible for intensive sampling of predevelopment and postdevelopment vegetation, soils, aquatic biota, and wildlife at the site through 1978. From 1979 through 1987, TAMU's Galveston Campus Department of Marine Biology conducted much of the lower-level long-term monitoring activities, under an IPA agreement with the university. The Environmental Laboratory (EL) at WES coordinated the long-term monitoring effort. A number of WES technical reports have been written on the BP field site* (Allen et al. 1978; Dodd et al. 1978; Lunz, Clairain, and Simmers 1978a; Lyon and Baxter 1978; Webb et al. 1978; Newling and Landin 1985) and present in great detail the site's chronology and development. Of particular importance to readers with BP interests are Allen et al. (1978), Webb et al. (1978), and Newling and Landin (1985), because these key BP site data will be only briefly summarized in this report.

223. Long-term site objectives were (a) to demonstrate that an unconfined sandy dredged material mound could be revegetated under moderate to severe wave energy conditions, (b) to demonstrate that the original site could remain a viable long-term marsh and upland habitat without additional management, and (c) to develop techniques for marsh establishment and test various levels of fertilizers, plant species, and propagule types.

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* J. W. Webb et al., 1979, "Comparison of Natural Marshes of Galveston Bay to Bolivar Peninsula Experimental Habitat Development Site in 1978," Unpublished Technical Report furnished to WES, Vicksburg, MS.

J. W. Webb, 1984, "Comparison of Natural Marshes of Galveston Bay to Bolivar Peninsula Experimental Habitat Development Site in 1983," Unpublished Technical Report furnished to WES, Vicksburg, MS.

J. W. Webb, 1985, "Annual Bolivar Peninsula Field Site Update: 1984," Unpublished Technical Report furnished to WES, Vicksburg, MS.

J. W. Webb, 1986, "Annual Bolivar Peninsula Field Site Update: 1985," Unpublished Technical Report furnished to WES, Vicksburg, MS.

J. W. Webb, 1987, "Annual Bolivar Peninsula Field Site Update: 1986," Unpublished Technical Report furnished to WES, Vicksburg, MS.

J. W. Webb and C. J. Newling, 1980, "Comparison of Natural Marshes of Galveston Bay to Bolivar Peninsula Experimental Habitat Development Site in 1979," Unpublished Technical Report furnished to WES, Vicksburg, MS.

Site Development

1974-1978

224. The original BP site deposit had been placed several years prior to the DMRP, but had not revegetated. The sandy mound was graded down to a gradual slope into the intertidal zone and protected with the construction of a dike made of large sandbags filled in place. A total of 270 treatment plots with replicates were marked, treated with various levels of fertilizers and different plant species, and seeded or sprigged. In the intertidal zone, smooth cordgrass and saltmeadow were the only species used. In the upland/high marsh zone, sand pine, live oak, salt cedar, wax myrtle, gulf croton, winged sumac, coastal Bermuda grass, bitter panic grass, and big bluestem were planted in various test plots. Methods, sampling, and analyses are detailed in Allen et al. (1978); Lunz, Clairain, and Simmers (1978a); and Webb et al. (1978). Aerial and ground-level photographs taken throughout the entire study documented changes over time.

225. In general, smooth cordgrass survived and spread throughout the lower two-thirds of the intertidal zone, while saltmeadow cordgrass survived and spread upward into the upland/high marsh zone. Few plants of these two species survived at other elevations. In the intertidal zone, seeded plots were complete failures because of either washout or too dry soil conditions. Fertilizer in this zone exhibited no long-term effect on plant growth.

226. By 1978, the upland/high marsh site showed marked changes over the original plantings. For example, only 5.4 percent of the bluestem survived, although at that time 96.5 percent of the live oak was surviving. While survival of planted species was generally very low, invasion of saltmeadow cordgrass, Drummond sesbania, and a number of "weedy" species created a dense stand of vegetation on the higher elevations of the BP site. Initially, fertilizer seemed to enhance survival of the grasses, wax myrtle, and sand pine, but had no long-term effect.

227. Predevelopment and postdevelopment aquatic sampling was done with seines, trawls, hoop nets, corers, and fish traps. Details are presented in Lyon and Baxter (1978), and Webb et al. (1978). A summary of findings shows that 47 fish species were caught, with Atlantic croaker, gulf menhaden, and white mullet dominating. After planting of the site, no change in fish abundance was noted, but a species composition change to bay anchovy, white

mullet, and Atlantic croaker in order of importance was noted. Species diversity was initially higher both outside the dike and on older nearby natural marshes that were sampled.

228. A very important finding was that abundant benthic invertebrates were found both on the dike and the site within 7 months, with the dominant groups being polychaete worms, tenanthurid isopods, and haustorid amphipods. Following dike construction, benthos was 1.5 times greater inside the dike than outside and 1.5 times greater again in the planted versus the unplanted portions of the site.

229. Extensive wildlife surveys were conducted and are detailed in Allen et al. (1978), Dodd et al. (1978), and Webb et al. (1978). From 1974-1978, 135 bird species were observed using the BP site. Least terns, Wilson's plovers, killdeer, brown-headed cowbirds, red-winged blackbirds, common nighthawks, and scissor-tailed flycatchers nested in the grass and bare areas of the site. The fence erected to keep feral goats from grazing the study site kept some of the mammals found on the island out, but eastern cottontails, marsh rice rats, and hispid cotton rats were still abundant on the site, and raccoons, armadillos, and other small animals found their way onto the site to feed. During this time, 14 reptilian and amphibian species were observed in the site upland.

1979-1982

230. In 1978, three reference marshes were selected in Galveston Bay; these were similar in wind and wave fetch and other features to the BP site for comparison purposes (Figure 25). One site (Pepper Grove) was an island and was located to the east of BP; the other two (Eight-Mile Road and Jamaica Beach) were on the shoreline on Galveston Island. Elevational checks were made to be sure that sampling was conducted in the same plant zones and that soil and plant samples were taken at the four sites in 1979. Each year following, only vegetation sampling was done, generally in the fall of the years of 1980 through 1987. Parameters measured included biomass, stem density, stem height, species composition, percent cover, and seed production. Data through 1982 are detailed in Newling and Landin (1985) and are summarized in the following paragraphs.

231. In 1978 and 1979, measurements indicated that the BP site was still newly developing. It had lower root biomass, stem density, and percent cover. The BP site was also different from the reference marshes in that stem

height, overall biomass of planted species, and aboveground biomass were greater than for any of the reference marshes. Table 29 presents representative 1979 data from Newling and Landin (1985). The exception was the Pepper Grove site, which was closest to the BP site and had similar soils. Percent cover at these two sites were equal, while percent cover at Eight-Mile Road and Jamaica Beach was both much greater than at the other two sites. An observation that became apparent when sampling was conducted across various elevations at the four sites was that for all four, biomass, percent cover, and stem density were greatest at the lowest elevations, while litter and dead biomass were greatest in the upper marsh zones. The phenomenon of high aboveground biomass and low belowground biomass is a common occurrence in new marshes because of the dynamic and rapidly evolving system where root biomass and structure have not had time to develop to the density usually found in older, established marshes.

232. By 1982, belowground biomass had reached a level that it fell into the range of variability of the three reference sites. At the same time, aboveground biomass continued to exceed or equal the reference sites. Other measurements at BP such as percent cover, species diversity, stem height and density, and flowering all approximated the three reference sites (Table 30).

233. The entire BP site was vegetated inside the fence. Where reference plots had been planted outside the fence and smooth cordgrass had colonized outside the fence, it had been grazed to within 5 to 10 cm of the ground by the goats. Smooth cordgrass just across the fence was 130 to 150 cm high, illustrating dramatically the impacts of grazing on intertidal marsh. It should be noted that at this phase of site development, small mammals that were able to penetrate the fence were grazing heavily on the upland grasses and woody vegetation; this heavy grazing probably had an influence on the decline of these grasses and vegetation and their replacement by saltmeadow cordgrass, which was not grazed by these animals.

234. Also by 1982, there was an unexpected occurrence at the BP site: the entire sandbag dike, which had been slowly eroding and breaking apart over time, had been colonized by oysters. A dense layer of oysters of all sizes formed a reef that effectively served as a breakwater for the planted marsh and no doubt had a role in protection of the site. On the side slopes where sandbags had been placed to prevent wave action from encroaching on young

Table 29

Summary of Vegetation Data Collected at the BP Habitat Development Site and Three Reference Areas, Fall 1979

Measurement	Bolivar Peninusla	Pepper Grove	Eight-Mile Road	Jamaica Beach
Mean aboveground biomass of live smooth cordgrass, g/sq m*	490.6 (75.6)**	448.2 (79.4)	479.6 (126.7)	458.5 (79.4)
Mean stem density of live smooth cordgrass, No./sq m*	201.7 (31.8)	246.4 (44.7)	255.0 (63.4)	356.2 (54.4)
Mean percent cover*	23.1 (2.9)	27.5 (5.1)	17.0 (4.1)	32.1 (4.0)
Mean height of smooth cordgrass, cm	77.9 (7.5)	79.6 (6.3)	81.6 (8.5)	63.0 (5.0)
Mean stem density of annual glasswort, No./sq m*	140.5 (53.6)	0 (0)	2.0 (1.4)	51.7 (40.1)
Mean aboveground biomass of annual glasswort, g/sq m†	25.4 (8.2)	0 (0)	2.7 (1.5)	14.5 (11.0)
Aboveground biomass of all other species, g/sq m	87.9 (40.2)	125.8 (53.2)	91.4 (21.7)	137.0 (42.6)
Total aboveground biomass, g/sq m	604.0 (64.9)	574.0 (84.4)	573.7 (118.2)	610.0 (64.3)
Belowground biomass (g/sq m)*				
0-10 cm	743.0 (96.3)	1,076.4 (176.2)	1,040.9 (146.4)	1,567.7 (150.8)
10-20 cm	372.6 (44.3)	666.5 (108.3)	592.6 (95.4)	651.5 (66.7)
20-30 cm	166.2 (27.3)	401.1 (62.2)	340.2 (58.5)	375.0 (37.2)
0-30 cm	1,281.8 (129.7)	2,144.0 (329.4)	2,007.7 (244.5)	2,594.2 (197.2)

Source: Newling and Landin (1985).

* Significant differences ($P < 0.05$) occurred between areas.

** Standard deviations of mean are in parentheses.

† Significant differences ($P < 0.01$) occurred between areas.

Table 30

Summary of Vegetative Data Collected at the BP Habitat Development Site and Three Reference Areas on 26-27 October 1982*

Species	Bolivar Peninsula				Pepper Grove Marsh				Eight-Mile Road Marsh				Jamaica Beach Marsh			
	Stem Density Stems/sq m	Mean Stem Height cm	Frequency of Occurrence %	Mean No. Flowering Stems/sq m	Stem Density Stems/sq m	Mean Stem Height cm	Frequency of Occurrence %	Mean No. Flowering Stems/sq m	Stem Density Stems/sq m	Mean Stem Height cm	Frequency of Occurrence %	Mean No. Flowering Stems/sq m	Stem Density Stems/sq m	Mean Stem Height cm	Frequency of Occurrence %	Mean No. Flowering Stems/sq m
Saltwort									7.8	12.4	37.5	0				
Saltgrass	20%**	33.6	25	6.0	40.4%	45.7	7.5	52.0	58.8	21.2	25	14.8				
Fimbristylis	1%**	42.3	25	1.8												
Saltflat grass									5%**	13.4	25	0				
Perennial glasswort	51.0	22.1	25	0					2.8	8.6	12.5	0	20%**	34.6	50	0
Smooth cordgrass	173.8	92.7	75	66.2	161.2	72.4	100	30.0	115.5	54.2	75	29.0	196.0	40.4	100	24.2
Saltmeadow cordgrass	1%	59.6	25	1.2												
		$\bar{X}$ = 50.1				$\bar{X}$ = 59.0				$\bar{X}$ = 22.0				$\bar{X}$ = 37.5		
	Mean percent cover = 60.7%				Mean percent cover = 74.1%				Mean percent cover 32.5%				Mean percent cover = 55.0%			

Source: Newling and Landin (1985).
* Based on eight 0.5-sq m quadrats/site at random locations throughout the intertidal zone.
** Estimate of percent species cover for area; stem count not obtained.

plants from the sides, so much sediment had been trapped that the bags were buried in the sand and dense vegetation.

235. Elevational differences continued to be important both at the field site and at the reference marshes (Table 31). Smooth cordgrass along the intertidal edge of the marsh averaged 1.0 m in height and was shortest just before it phased out into high marsh. In a belt transect across elevations from lowest to highest zones, the following species were encountered by order of appearance: smooth cordgrass, saltmeadow cordgrass, saltgrass, perennial glasswort, fimbristylis, groundsel tree, marsh fleabane, seaside goldenrod, American three-square, saltmarsh aster, plantain, Indian blanket, common ragweed, aster, camphorweed, soft camphorweed, Drummond sesbania, fleabane, broom sedge, bushy beardgrass, and beach-tea. This species diversity across elevations held true throughout the remainder of the study (1987). At the three reference sites, lowest elevational plants were always smooth cordgrass and then graded into saltmeadow cordgrass and saltgrass. There was very little diversity in these older marshes, with some occurrence of saltwort, glasswort, and saltflat grass at Eight-Mile Road, with additions of sea lavender, camphorweed, seaside goldenrod, and marsh elder at higher elevations.

236. From 1978-1981, almost no wildlife observations were made at BP because the primary focus was on vegetation establishment. In 1982, a series of surveys began that allowed documentation over time of the species using the BP site. In general, numerous species of herons, egrets, gulls, terns, shorebirds, ibises, and other waterbirds fed along the shoreline of the marsh, while clapper rails, marsh wrens, sharp-tailed sparrows, eastern meadowlarks, killdeer, and willets nested there. More important than just noting occurrence at BP is that wildlife species diversity was greater than at the reference sites. Higher numbers of wading birds were found at Eight-Mile Road probably because more open-water pockets occurred in that marsh. The same mammals and other animals recorded during the early phase (1974-1978) continued to be found on the site throughout the study (Table 32).

237. In late 1978, the BP site and the Jamaica Beach site were sampled for aquatic organisms and detailed soil analyses. Results were detailed in Newling and Landin (1985) and are summarized below and in Table 33. The smooth cordgrass at the BP site had trapped enough fines and other sediment for BP soils to more closely resemble the natural marsh. However, aquatic

Table 31

Summary of Vegetation Data by Elevation at the BP Habitat Development Site and Three Reference Areas, Fall 1979

Measurement	Elevations Above Mean Low Water, m* 0.20	0.31	0.43	0.54	0.66
Mean aboveground biomass of live smooth cordgrass, g/sq m	738.2 (72.1)**	1,076.0 (100.5)	449.7 (57.9)	66.6 (19.3)	15.6 (7.0)
Mean stem density of live smooth cordgrass, No./sq m	295.3 (30.0)	563.1 (48.6)	404.1 (58.1)	52.0 (15.4)	9.7 (4.1)
Mean percent cover	21.3 (2.6)	50.3 (3.9)	25.5 (3.6)	11.4 (3.8)	16.1 (4.6)
Mean height of smooth cordgrass, cm	100.7 (4.9)	98.3 (4.2)	57.2 (3.4)	36.0 (3.9)	32.3 (5.1)
Mean stem density of annual glasswort, No./sq m	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	43.7 (25.7)	198.6 (75.6)
Mean aboveground biomass of annual glasswort, g/sq m	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	14.4 (7.0)	38.9 (15.0)
Aboveground biomass of all other species, g/sq m	1.1 (1.1)	101.3 (55.3)	55.0 (24.2)	143.5 (44.1)	251.9 (59.6)
Total aboveground biomass, g/sq m	739.3 (72.3)	1,177.3 (81.4)	504.8 (54.2)	224.5 (48.0)	306.3 (61.4)
Belowground biomass g/sq m					
0-10 cm	1,274.6 (155.8)	1,837.0 (167.2)	901.8 (126.2)	691.4 (92.4)	830.2 (196.2)
10-20 cm	763.5 (106.3)	720.4 (98.8)	505.9 (61.1)	530.2 (103.6)	330.5 (66.5)
20-30 cm	495.6 (69.7)	312.3 (42.9)	314.4 (57.6)	280.6 (56.3)	200.3 (38.0)
0-30 cm	2,533.7 (268.7)	2,869.7 (253.9)	1,722.1 (224.7)	1,502.2 (228.7)	1,361.0 (298.2)

Source: Newling and Landin (1985).

* All measurements were significantly different (P ≤ 0.0001) between elevations.

** Standard deviations of mean.

Table 32

Wildlife Observed at BP Habitat Development Field Site, 1974-1987

American avocet 1,2	American coot 1,2
American kestrel 1,4	American oystercatcher 1,2,3
American redstart 4	American robin 4
American white pelican 1,2,3	Bank swallow 1,2,3,4
Barn swallow 1,2,3,4	Belted kingfisher 1,2
Black-and-white warbler 4	Black-bellied plover 1,2,3
Black-crowned night-heron 1,2	Black-necked stilt 1,2
Blackpoll warbler 4	Black skimmer 1,2,3
Black tern 1,2	Black-throated green warbler 4
Blue-gray gnatcatcher 1,4	Blue grosbeak 4
Blue jay 1,4	Blue-winged teal 1
Brown-headed cowbird 1,4	Canvasback 1
Caspian tern 1,2,3	Cattle egret 4
Chimney swift 1	Clapper rail 1
Common grackle 1,2,3,4	Common nighthawk 1,2,4
Common tern 2,3	Common yellowthroat 4
Double-crested cormorant 1,3	Dunlin 1,2,3
Eared grebe 1	Eastern cottontail 1,4
Eastern kingbird 4	Eastern meadowlark 1,4
Eastern phoebe 4	Eastern wood-pewee 4
Field sparrow 1,2,4	Forster's tern 1
Goat 1,2,3,4	Gray catbird 1,4
Great blue heron 1,2	Great egret 1
Greater yellowlegs 1,2,3	Great-tailed grackle 1,2,3,4
Green-backed heron 1	Gull-billed tern 1,3
Hermit thrush 4	Herring gull 1,2,3
Hispid cotton rat 1,2,4	Hooded warbler 4
Horned toad 1,2,3,4	Horned lark 1,2,4
House mouse 1,4	House wren 1,4
Indigo bunting 4	Ipswich sparrow 1,4
Killdeer 1,2	Laughing gull 1,2,3
Least sandpiper 1,2,3	Least tern 1,2,3
LeConte's sparrow 4	Lesser yellowlegs 1,2,3
Loggerhead shirke 1,2,4	Long-billed curlew 1,2
Long-billed dowitcher 1,3	Magnolia warbler 4
Marbled godwit 1,2,3	Marsh wren 1,2
Mottled duck 1	Mourning dove 1,4
Nine-banded armadillo 1,2,4	Northern cardinal 1,3,4
Northern flicker 1,4	Northern harrier 1,2
Northern mockingbird 4	Northern oriole 4
Northern rough-winged swallow 1,2,3,4	Northern shoveler 1
Northern waterthrush 4	Olivaceous cormorant 1
Opossum 1,4	Orange-crowned warbler
Orchard oriole 4	Osprey 1

(Continued)

* Observations made in: 1 = original planted marsh; 2 = newest planted marsh; 3 = unvegetated control deposit; 4 = Goat Island upland.

Table 32 (Concluded)

Ovenbird 4
Palm warbler 4
Piping plover 1,2,3
Purple martin 1,2,3,4
Reddish egret 1
Red knot 1,2,3
Red-winged blackbird 1,2,3,4
Roseate spoonbill 1,2
Royal tern 1,2,3
Ruby-throated hummingbird 1,4
Sanderling 1,2,3
Savannah sparrow 1,4
Semipalmated plover 1,2,3
Slate-gray junco 4
Snowy egret 1,3
Song sparrow 1,4
Spotted sandpiper 1,2
Swamp sparrow 4
Tree swallow 1,2,3,4
Veery 4
Western sandpiper 1,2,3
White-eyed vireo 4
White ibis 1
Willet 1,2,3
Worm-eating warbler 4
Yellow-breasted chat 4
Yellow-throated warbler 4
Painted bunting 4
Pectoral sandpiper 1,3
Prothonotary warbler 4
Raccoon 1,2,4
Red-eyed vireo 4
Red-tailed hawk 1,2,3,4
Ring-billed gull 1,2
Rose-breasted grosbeak 4
Ruby-crowned kinglet 4
Ruddy turnstone 1,2,3
Sandwich tern 1,2,3
Scissor-tailed flycatcher 1,2,4
Short-eared owl 1,4
Snow goose 1
Solitary sandpiper 1,2,3
Sooty tern 2,3
Swainson's thrush 4
Tennessee warbler 4
Tri-color heron 1
Water pipit 1,2,4
Whimbrel 1
White-faced ibis 1
White-rumped sandpiper 1
Wilson's plover 1,3
Yellow-billed cuckoo 1,4
Yellow-rumped warbler 1,2,4
Yellow warbler 4

Table 33

Abundance of the Highest Order Dominant Macrobenthos at Both the BP Habitat Development Site and Jamaica Beach Reference Marsh

Species	May 1978 Outside Cage HD*	May 1978 Outside Cage JB*	July 1978 Outside Cage HD	July 1978 Outside Cage JB	September 1988 Outside Cage HD	September 1988 Outside Cage JB
Streblospio benedicti	1,225**	4,066	63	3,092	220	16,771
Heteromastus filiformis	5,009	597	434	270	465	503
Capitella capitata	57	1,565	434	270	465	503
Nereis succinea	69	31	19	31	13	31
Laeoneris culveri	13	25	0	31	0	471
Mediomastus spp.	553	0	0	0	25	13
Loandalia fauveli	842	0	591	0	440	0
Polydora ligni	38	333	0	6	0	31
Eteone heteropoda	170	19	0	6	6	0
Glycinde solitaria	31	25	0	0	38	0
Oligochaetes	13	38	0	31	0	1,640
Corophium spp.	0	1,188	0	25	0	2,728
Hargaria rapax	0	390	0	19	0	371
Paleomonetes spp.	13	13	82	0	50	0
Total	8,033	8,290	1,623	3,781	1,722	23,002
			Inside Cage HD	**Inside Cage JB**	**Inside Cage HD**	**Inside Cage JB**
Streblospio benedicti			283	8,195	659	24,668
Heteromastus filiformis			880	264	402	559
Capitella capitata			136	4,226	25	2,292
Nereis succinea			25	38	157	50
Laeoneris culveri			0	276	0	364
Mediomastus spp.			0	0	38	88

(Continued)

Source: Newling and Landin (1985).
* HD = Habitat development marsh; JB = Jamaica beach marsh.
** Individuals per square metre.

Table 33 (Concluded)

Species	May 1978 Outside Cage HD	May 1978 Outside Cage JB	July 1978 Inside Cage HD	July 1978 Inside Cage JB	September 1988 Inside Cage HD	September 1988 Inside Cage JB
Loandalia fauveli			723	0	666	19
Polydora ligni			0	0	0	13
Eteone heteropoda			0	6	0	6
Glycinde solitaria			13	0	25	0
Oligochaetes			0	132	0	942
Corophium spp.			0	50	6	4,547
Hargaria rapax			0	25	0	6
Paleomonetes spp.			107	0	63	0
Total			3,367	13,212	2,035	33,554

Species	Former Cage HD	Former Cage JB
Streblospio benedicti	301	20,686
Heteromastus filiformis	477	760
Capitella capitata	13	396
Nereis succinea	63	56
Laeoneris culveri	0	578
Mediomastus spp.	127	0
Loandalia fauveli	590	0
Polydora ligni	6	13
Eteone heteropoda	0	19
Glycinde solitaria	50	6
Oligochaetes	0	2,035
Corophium spp.	6	69
Hargaria rapax	0	352
Paleomonetes spp.	38	0
Total	1,671	24,970

organism differences were noted between the two sites. For example, *Macoma constricta* occurred only at BP, but both sites were dominated by polychaete worms, which constituted over 90 percent of all individuals and 55 percent of all species collected. Of those occurring on both sites, densities of *Streblospio benedicti* and *Capitella capitata* were highest at Jamaica Beach, while *Heteromastus filiformis* densities were highest at the BP site.

238. There was more macrobenthos at Jamaica Beach (silty soil) at all sampling periods than at BP (sandy soil), with marked increases occurring in the fall at Jamaica Beach and no corresponding increase at BP. In caging experiments to determine predation pressures, all species exhibited a level of increase in numbers from the cages that excluded fish, crabs, and birds. Two years after planting, the benthic community at BP had not reached the abundance found at Jamaica Beach marsh, but was expected to become more similar over time. No further benthic or fish sampling work was conducted at BP after 1978.

1983-1987

239. Variations in the monitoring work at BP occurred from 1983 through 1987, in that Galveston District dredged the GIWW again and placed the sandy dredged material on either side of the original BP site. Under an agreement with the District, the EL at WES conducted a series of erosion control plantings on the new mound (without grading for elevation) located to the west of the original site. The mound to the east of the original site was left unvegetated to serve as a control. All three sites are now part of the long-term monitoring effort. In 1985, during maintenance dredging, the District also placed sandy dredged material in the edge of the existing planted marsh at the original site to see how long it would take for it to recover and what species would colonize the new deposit. This smothering test was also included in the overall study.

240. Vegetation sampling along elevational lines at one of the three reference marshes (Jamaica Beach), the original BP site (planted in 1976), the newly planted BP site (in 1984), and the unplanted control mound continued through 1987. Manpower and budget constraints caused selection of only one of the reference marshes for continuation, and more data were available for Jamaica Beach than for the other two marshes. The only fisheries and benthos comparisons had been made with Jamaica Beach in 1978, and it had continuously been sampled for vegetation since 1978.

241. Species composition of the original BP marsh and Jamaica Beach was very similar, and elevational differences continued to be noted in percent cover, stem density, and stem height (Table 34) at both sites. Stem density was consistently lower in the middle zone at BP than at Jamaica Beach. This could have been a result of the BP marsh being much wider than the Jamaica Beach marsh. At both marshes, the tallest, most dense smooth cordgrass was always nearest the marsh edge, and more plots close to the edge were sampled at Jamaica than at BP. There were significant differences noted in glasswort occurrence at higher elevations. Other species found in plots could be considered almost incidental because of their scarcity.

242. At both sampled sites, smooth cordgrass dominated the intertidal zone from mean low water to mean high water. Saltgrass, Virginia glasswort, Bigelow's glasswort, and saltwort occurred in relatively small numbers in the high marsh zone at both sites.

243. One of the major differences between BP and Jamaica Beach was the distance for wind fetch and the potential for erosion at BP. Jamaica Beach was relatively protected compared with the 42-km wind fetch at BP. In 1986 and 1987, erosion accelerated at the original BP site because local citizens were harvesting the oysters off the old sandbags. This left the marsh unprotected by any erosion control structure. Marker poles placed in 1985 indicated that by 1987 the BP site had eroded along its shoreline an average of 5.9 m where the protective structure had been removed. Exposed smooth cordgrass rhizomes at the shoreline were visible, indicating active erosion. The removal of protection was probably the most important reason any erosion was occurring at BP; however, a second factor also was noted. Sand and sediment accretion in the planted marsh caused the marsh elevation along the shoreline to become higher and to form a slight berm. The toe of this berm had eroded, causing a cut bank, which sloughed off into the bay during times of high wave energy.

244. The sandy mound placed on the western edge of the original marsh in 1985 was monitored by driving permanent metal stake posts in the old marsh prior to dredging. In this way, the depth of dredged material and the amount of mounding could be recorded. The dredged material did not flow evenly over the site, and mounding took place even with the discharge occurring for less than 2 hr. Sand depths ranged from 0 to 38 cm across the new deposit. Vegetation was completely buried in the center of the mound. Plots were

Table 34

Comparison of Vegetation Parameters at BP Field Site and Jamaica Beach Reference Marsh, 1985 and 1987

Site	Stem/sq m Density 1985	Stem/sq m Density 1987	Stem Height, cm 1985	Stem Height, cm 1987	Frequency of Occurrence, % 1985	Frequency of Occurrence, % 1987	Percent Cover 1985	Percent Cover 1987
Bolivar Peninsula (1976 planted marsh)								
Smooth cordgrass*								
Shoreline	201.8	--	70.8	--	100.0	--	47.8	--
Lower zone	162.4	88.8	74.2	81.8	100.0	100.0	58.3	58.3
Middle zone	170.6	142.0	64.6	58.7	100.0	100.0	40.0	47.5
Upper Zone	140.0	106.0	41.6	42.0	50.0	50.0	21.1	28.7
Saltgrass	--	--	--	--	--	--	6.4	0.0
Virginia glasswort	--	--	--	--	--	--	2.1	2.5
Bigelow's glasswort	--	--	--	--	--	--	0.6	2.8
Saltwort	--	--	--	--	--	--	0.1	0.7
Fimbristylis	--	--	--	--	--	--	<0.1	<0.1
Saltmeadow cordgrass	--	--	--	--	--	--	<0.1	<0.1
Jamaica Beach Marsh								
Smooth cordgrass*								
Shoreline	--	--	--	--	--	--	--	--
Lower zone	147.6	221.2	67.2	71.5	100.0	100.0	40.0	38.5
Middle zone	282.4	278.8	48.5	54.0	100.0	100.0	81.0	53.3
Upper zone	152.4	103.0	32.9	33.3	75.0	75.0	57.6	21.7
Saltgrass	--	--	--	--	--	--	0.0	0.0
Virginia glasswort	--	--	--	--	--	--	1.0	4.2
Bigelow's glasswort	--	--	--	--	--	--	2.0	0.0
Saltwort	--	--	--	--	--	--	2.4	0.0
Fimbristylis	--	--	--	--	--	--	0.0	0.0
Saltmeadow cordgrass	--	--	--	--	--	--	0.0	0.0

* Only smooth cordgrass occurred on shorelines and in lower and middle zones.

sampled to measure vegetation recovery and colonization (Table 35). Smooth cordgrass was smothered and could not penetrate the depth of dredged material in the middle of the mound, although it had recovered and continued to grow along the fringes of the new deposit. High marsh zones smothered by the new deposit had sparsely colonized by 1987 with isolated clumps of Bigelow's glasswort, Virginia glasswort, saltmeadow cordgrass, and American three-square. The smooth cordgrass that had originally grown in the intertidal elevations of the BP site appeared to have been replaced with a young high marsh community dominated by saltmeadow cordgrass and American three-square.

Table 35

Percent Cover of Colonizing Plant Species on the Smothered Portion of the Original BP Marsh in 1987

Species	Percent Cover*
Smooth cordgrass	7.5
American three-square	3.4
Virginia glasswort	1.8
Bigelow's glasswort	1.5
Saltmeadow cordgrass	1.0
Common ragweed	<1
Goosefoot	<1
Fimbristylis	<1
Blue curl	<1
Camphorweed	<1
Marsh elder	<1
Seaside goldenrod	<1
Sea blite	<1

* Species recorded from sample plots one full growing season after dredged material was placed over the planted marsh.

245. The "control" mound on the east side of the original BP site that was left unplanted had not vegetated by 1987. Sample plots on this site were mostly bare sand, with isolated clumps of dropseed, fimbristylis, saltmeadow cordgrass, and nutsedges. Smooth cordgrass did not occur on this mound, and the unvegetated edges were steadily eroding back into Galveston Bay.

246. The newest BP site on the fan deposit on the weste n side of the original site was planted in 1984 in experimental plots behind floating- or fixed-tire breakwaters, in erosion control mat, and in plant rolls. It had

spread from a few small plots to more than 2 ha of smooth cordgrass marsh with a mean percent cover of 70 percent. All of the erosion protection structures or features were causing sediment trapping, and some scouring of plants was taking place from the side of the test plots. High water in the bay caused scour behind test plots and in some cases left the smooth cordgrass plots like islands along the shoreline. These data from the newest BP marsh are preliminary and will be the subject of a later WES technical report.

Long-Range Plans

247. Since the BP site is part of an ongoing disposal site (Goat Island), Galveston District will continue to look for alternatives for low-cost stabilization of dredged material along the bay shore. Long-term monitoring of the BP site will continue under District request through 1989 to determine which of the erosion control structures applied to the newest marsh have more applicability for rapid stabilization. The District is especially interested in determining whether or not it can place dredged material over an existing marsh in the GIWW and get marsh recovery with the same species and as much productivity.

248. In this regard, WES is already monitoring for Galveston District a high marsh at East Matagorda Bay, Texas, that was deliberately smothered in a cooperative demonstration project between the State of Texas and the District. Comparisons of the data from the BP smothering test and the East Matagorda Bay test will be made, although preliminary data indicate that disposal techniques have to be refined because the dredged material was applied too deep in most parts of both sites. This significantly affected vegetation survival and recovery.

249. Marsh development, shoreline stabilization, and other beneficial use efforts at various levels will continue at the BP site in the near future. Techniques refined at the BP site for marsh development can be applied to other sites along the northern gulf coast where long wind fetches and bare sandy or loamy soils exist. Especially important is the methodology for erosion control structure modification that has been developed since 1984, since all of these methods are less expensive than sandbagging and less than one-fourth as expensive as stone armor for site protection.

Summary

250. The BP field site was established on an old sandy disposal mound on Goat Island in Galveston Bay, Texas. Test plots of smooth cordgrass at intertidal elevations and a mixture of upland grasses and trees were planted and monitored from 1976 through 1987. In 1978, three reference marshes were selected for comparison with to the BP site, and in 1983, two additional dredged material mounds to the east and the west of the BP site were also added to the long-term monitoring effort. A small smothering study was also added at the original BP field site in 1985 after more dredged material was applied over the western edge of the existing marsh.

251. Smooth cordgrass was the only plant species that survived and spread at intertidal elevations at the BP sites. Most of the planted upland grasses and trees did not survive, and the upland site was invaded by salt-meadow cordgrass that had been planted in the middle and high marsh zones and by a number of invading species such as marsh fleabane, Indian blanket, and broom sedge.

252. Erosion control structures such as the sandbags installed around the original planted marsh, floating- and fixed-tire breakwaters, and erosion control matting proved to be effective methods for protecting developing intertidal marsh and will continue to be refined at the BP and other CE marsh development sites.

PART XI: SALT POND #3, SOUTH SAN FRANCISCO BAY, CALIFORNIA

Background

253. The Salt Pond #3 (SP3) habitat development field site is located on the north side of Alameda Creek Flood Control Channel in South San Francisco Bay (Figure 27). The SP3 site was an old 40.4-ha diked saltwater evaporation pond prior to dredged material disposal into the pond and subsequent habitat development (Figure 28). The region averages 40 cm of precipitation that falls mostly in winter months, and the summers are extremely dry.

254. Sediment from San Francisco Bay is usually very fine-grained silt and sand, and except for protected coves and pockets, very little marsh remains in the bay system. There are extensive mud flats that are exposed at low tide, and the bay has a tidal range of 1.5 to 3.2 m. Tidal marshes in the bay are dominated by Pacific cordgrass and Pacific glasswort, while the higher marshes consist of a mixture of frankenia, sea blite, saltbushes, sand spurry, and saltgrass.

255. The SP3 site was selected for study during the DMRP because it represented a large west coast fine-grained disposal site that would not have revegetated readily without habitat development technique applications. The study had actually been initiated prior to the DMRP in 1972 by San Francisco District and was continued under the DMRP.

256. All engineering, surveying, and leveling work, including construction of the tidal channels and the breach of the salt pond dike, was carried out by San Francisco District. Early site data collection was contracted to San Francisco Bay Marine Research Center. Long-term monitoring was conducted by the EL at WES, and a number of technical reports and papers detailing study results have been written about this field site* (Morris et al. 1978; Newling

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* S. Moorhouse, 1977, "Avian Survey of Salt Pond #3 and Reference Marsh," Unpublished Technical Report prepared for WES, Vicksburg, MS.
J. H. Morris and C. L. Newcomb, 1977, "Salt Pond #3 Marsh Site Botanical Studies," Unpublished Technical Report prepared for WES, Vicksburg, MS.
J. H. Morris, C. L. Newcomb, and B. R. Wells, 1979, "Marshland Plant and Sediment Characteristics, South, San Francisco Bay, CA," Unpublished Technical Report prepared for WES, Vicksburg, MS.

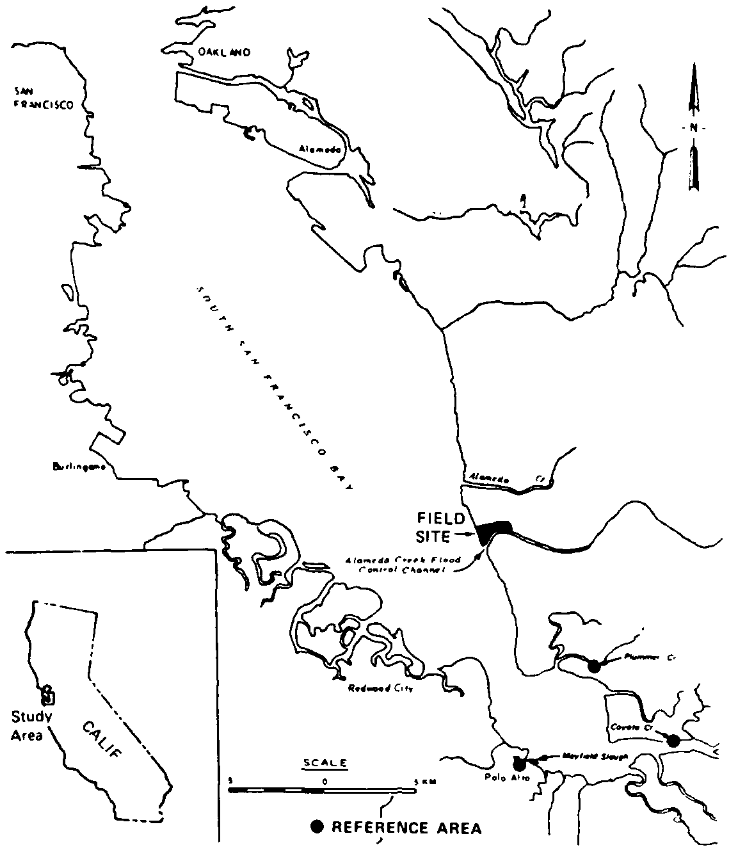

Figure 27. Salt Pond #3 in South San Francisco Bay, California

Figure 28. Salt Pond #3 1 year after it was planted, showing the experimental plots, the configuration of the pond, and the breach in the dike and tidal channels

and Landin 1985; USAED, San Francisco 1976), and early data will be briefly summarized in the following section.

Site Development

1972-1978

257. In 1965, SP3 was abandoned as a salt pond. In 1972, the District breached the dike to allow tidal influx. In 1974, the District closed the dike breach and placed 500,000 cu m of very fine-grained silty clay dredged material inside the dike. In 1975, the dike was again breached, and a tidal channel was cut into the dredged material from the breach. Large desiccation cracks formed in the site and were considered to pose a special problem with planting techniques, especially seeding. Therefore prior to planting, a lightweight dozer was used, three passes, to close the cracks.

258. In 1976 and 1977, the site was sprigged with Pacific cordgrass, Pacific glasswort, and pickleweed. Sprigs came from a nearby donor marsh and were planted according to the experimental design detailed in Morris et al. (1978). Plant survival, stem density, and biomass were monitored on all plots, and evaluations on optimum plant spacing, substrate preparation, planting techniques, and season of planting were made. Seeds of these species were also used in some plots to determine if seeds could survive in fine-textured, highly saline dredged material.

259. The test plots of seeds were total failures. The test plots with sprigs were generally very successful. Transplants on 0.5-m centers gave better results than wider spacings. These sprigs were placed into the substrate by hand rather than by mechanical planter, and those sprigs placed in dredged material that still had the desiccation cracks had a more than 50-percent greater survival rate than other plots and were the most successful plots. These plots had a visually dense plant cover by 1978. Pacific cordgrass survived in the lower two-thirds of the SP3 site, while pickleweed and Pacific glasswort grew in the upper one-third of the planted zone by 1978. By the end of the study in 1986, the entire high marsh and rest of the 41-ha site were vegetated with the two latter species, and the Pacific cordgrass had covered the entire lower marsh zone.

260. Substrate samples taken in 1975 showed that the dredged material placed over the salt residue in the pond had 70 to 100 ppt salt, levels which

are toxic to seeds and seedlings of Pacific cordgrass. This salinity readily explained why seeds sown on the site did not germinate.

261. Benthic invertebrates sampled in 1976 and 1977 in the newly planted marsh revealed nine polychaetes species, seven amphipod species, an isopod species, and a gastropod species. In addition, four other groups were found in small numbers. All benthic populations increased over time as the saltmarsh developed. All populations at SP3 were also less than those at a nearby reference area on Alameda Creek, an effect of the high salinity and the newness of the planted marsh. No fish data were collected at any time during the SP3 study.

262. Insect sampling from 1974 through 1977 showed that no insects occurred on the site until the marsh was planted. By 1977, nine species were found in the upper marsh and two in the lower marsh. These insects were brine flies, spider mites, and beetles.

263. Wildlife use at SP3 has been unusual in that in spite of being a shoreline marsh where many animals would be expected, no animals but birds were found throughout the study, with the exception of Norway rats living in riprap along one side of the dike. Dog tracks (probably pets from a nearby residential area) were the only other mammal sign found. While 49 bird species were sighted at Alameda Creek over a 2-year period, only 39 species were observed at SP3. The most abundant birds, accounting for almost all of those recorded, were waterbirds, waterfowl, and a number of shorebird species feeding on the site mud flats and marsh fringes.

1979-1982

264. Both qualitative data at each site visit and quantitative data on soils and vegetation were collected during this phase of SP3. Insect and benthic data were not collected after 1977, and wildlife observations were limited to counts, notes on habitats used, and general survey data. Three reference marshes as similar as possible to conditions found at the SP3 site were selected at Mayfield Slough, Plummer Creek, and Coyote Creek. Soils and soil chemistry data were detailed in Newling and Landin (1985) and will not be repeated here except to note that salinity levels declined slightly during this period, that the salinities for all four sites were similar, and that soil moisture and ammonium nitrogen were much lower in SP3 than in any of the reference marshes.

265. Pacific cordgrass is a very slow-growing species, and a planted stand of this species could take up to 10 years to develop adequately. In vegetation sampling through 1978, this slow growth was evident in the amount of biomass produced at SP3 compared with the three older, established marshes (Table 36). In stands where Pacific cordgrass had become well established at SP3, however, percent cover was 75 to 100 percent of all quadrats sampled by 1978.

266. From 1979 through 1982, no biomass samples were taken from SP3. However, stem density, stem height, frequency of occurrence, flowering stems, and percent cover were recorded in random quadrats along transect lines across both the high marsh and the low tidal marsh (Table 37). These data are presented in detail in Newling and Landin (1985) and summarized as follows.

267. By 1982, percent cover had increased for Pacific cordgrass in the densest stands from 1978 sampling and over the entire lower marsh. The entire SP3 site was visually covered with Pacific cordgrass in the lower tidal zone and with pickleweed and Pacific glasswort mixtures in the upper zone. Percent cover in quadrats of the two *Salicornia* species was slightly lower than that of Pacific cordgrass. The only real plant diversity that had occurred on the SP3 site was on the dike surrounding the area and the toe of the dike. A total of 19 species in low numbers were found in this area and included dodder, frankenia, groundsel tree, gumweed, hedge mustard, ice plant, sea blite, New Zealand spinach, orach, rabbitfoot grass, roseate orach, saltgrass, saltmarsh sand spurry, smooth cordgrass (one large stand by the dike), and winterfat, in addition to the three planted species.

268. By 1982, the SP3 site received considerable avian wildlife use (Table 38) that equaled species diversity in nearby Alameda Channel and adjacent open salt ponds. During this period, 35 bird species, Norway rats, and domestic dogs were observed using the area. Use undoubtedly was greater due to the habitat diversity created by the surrounding dikes and the tidal creek within SP3.

1983-1986

269. During the last years of the SP3 study, long-term monitoring efforts were generally limited by manpower and budget constraints to general reconnaissance visits that did not involve intensive vegetation or soils data collection. Vegetation measurements taken in random quadrats in both the lower zone and the higher marsh zone showed a continued trend towards

Table 36

Summary of Biomass Measurements from the Salt Pond #3 Habitat Development Site and Three Reference Areas During 1978

Measurement	Site				
	Pond #3	Plummer Creek	Coyote Creek	Mayfield Slough	Mean
Standing crop biomass of Pacific cordgrass, g/sq m	450c*	678c	802b	1,052a	746
Standing crop biomass of glassworts, g/sq m	120a	1,373b	1,491b	1,639b	1,156
Root biomass of Pacific cordgrass by depth					
0-5 cm	0.46**	1.23	1.00	2.78	1.37ab
5-10 cm	0.65	1.26	1.25	3.18	1.59a
10-15 cm	0.85	0.94	1.44	3.17	1.61a
15-20 cm	0.76	1.14	1.23	2.67	1.45a
20-25 cm	0.41	0.67	1.41	2.18	1.09b
Mean	0.60c	1.05b	1.21b	2.80a	1.42
Root biomass of glassworts by depth					
0-5 cm	0.34**	6.18	4.02	4.79	3.83a
5-10 cm	0.48	2.81	3.26	3.09	2.41b
10-15 cm	0.11	3.19	2.25	3.11	2.16b
15-20 cm	0.12	2.78	1.82	3.43	2.04b
20-25 cm	0.15	2.94	1.14	2.74	1.74b
Mean	0.24b	3.58a	2.50a	3.43a	2.44
Stem height of Pacific cordgrass, cm	86.8b	89.2b	90.7b	120.3a	96.8
Layer thickness of glassworts, cm	34	48	43	49	44

Source: Newling and Landin (1985).

* Means followed by the same letter are not significantly different ($P \cong 0.05$).

** Root biomass reported as g/233 cu cm (the volume of the 7.7- by 5-cm core section).

Table 37

Summary of Vegetation Data Collected at the Salt Pond #3 Habitat Development Site on 2 September 1982

Species	Lower Zone*				Upper Zone*				Mean of Both Zones*			
	Stem Density Stems/sq m	Mean Stem Height cm	Frequency of Occurrence %	Mean No. Flowering Stems/sq m	Stem Density Stems/sq m	Mean Stem Height cm	Frequency of Occurrence %	Mean No. Flowering Stems/sq m	Stem Density Stems/sq m	Mean Stem Height cm	Frequency of Occurrence %	Mean No. Flowering Stems/sq m
Pacific cordgrass	154.0	96.4	100	102	1.0	29.5	25	0	104.8	83.1	62.5	51.0
Glasswort	61.0	51.3	100	--	457.5	36.6	100	--	259.2	44.0	100	--
	215.0	= 73.8			458.5	= 33.0			364.0	= 63.6		
	Mean percent cover = 81.5%				Mean percent cover = 78.2%				Mean percent cover = 79.9%			

Source: Newling and Landin (1985).
* Based on four 0.5-sq m quadrats.
** Based on eight 0.5-sq m quadrats.

Table 38

Wildlife Observed at Salt Pond #3, 1979-1984

SP3	All Reference Areas Combined
American avocet 2*	American avocet
American kestrel 3	Barn swallow
American white pelican 4	Black-bellied plover
Barn swallow 1,2,3,4	Black-necked stilt
Black-bellied plover 1,2	Blue-winged teal
Black-shouldered kite 3	Brant's cormorant
Black-crowned night-heron 1,2	Brewer's blackbird
Black-necked stilt 1,2	California gull
Brant's cormorant 4	Canvasback
Brewer's blackbird 3,4	Caspian tern
Brown pelican 4	Cliff swallow
California gull 4	Double-crested cormorant
Caspian tern 4	Herring gull
Cliff swallow 1,2,3,4	Killdeer
Dog 4	Least sandpiper
Double-crested cormorant 2,4	Least tern
Dunlin 2	Lesser scaup
Forster's tern 1,2	Long-billed curlew
Great blue heron 1,2,4	Mallard
Great egret 1,2	Marbled godwit
Herring gull 4	Northern phalarope
Horned lark 3,4	Ring-necked duck
Killdeer 2,3	Ruddy turnstone
Least sandpiper 2	Sanderling
Long-billed curlew 2	Semipalmated plover
Long-billed dowitcher 2	Snowy egret
Marbled godwit 1,2	Snowy plover
Marsh wren 1	Spotted sandpiper
Northern harrier 1,2,3,4	Tree swallow
Northern phalarope 2	Western gull
Peregrine falcon 2,3,4	Western sandpiper
Saltmarsh song sparrow 1,3	Whimbrel
Sanderling 1,2	Willet
Semipalmated plover 2	American white pelican
Snowy egret 1,2	Brown pelican
Snowy plover 2	
Spotted sandpiper 1,2	
Tree swallow 1,2,3,4	
Western gull 4	
Western meadowlark 3	
Western sandpiper 2	
Whimbrel 2	
Willet 1,2,4	
Norway rat 3,4	
Dog 4	

* Observations noted at: 1 = planted marsh; 2 = adjacent tidal channel or shoreline; 3 = naturally colonized marsh; 4 = dikes only.

increased percent cover, stem density, and maturity of the planted marsh (Table 39). By 1986, the entire 41-ha salt pond had completely vegetated. Large expanses of the pond that had not been planted had colonized and densely grew with glasswort and pickleweed. In the lower zone, Pacific cordgrass neared 100-percent cover throughout the intertidal area.

270. Wildlife use did not change appreciably, and the species listed in Table 38 still continued to be found at SP3. No new species were noted, indicating that the marsh was reaching a point of stability. Feeding shorebirds, waterbirds, and waterfowl continued to be the primary users of the SP3 field site.

Summary

271. The SP3 field site was begun before any of the other DMRP major field sites and has evolved slower than the others because of the growth habits of the plant species used at the site. The site was planted with Pacific cordgrass, Pacific glasswort, and pickleweed and took 11 years to achieve total plant cover. Wildlife use of SP3 reached a high soon after the marsh was planted and has continued at this level since 1978. In the only benthic work done at SP3 (1976-77), benthos was found to be very diverse, but of lower populations than nearby older marshes. No samples were taken after the marsh reached maturity.

272. The SP3 site was used to test a variety of methods involving both mechanical planting and hand-planting on silt/clay substrates. It was found that hand-planting sprigs (not seeds) in undisturbed substrates yielded the greatest plant survival and growth. Even though the species selected for planting at SP3 took twice as long to reach the same level of growth as other DMRP sites, no other species are recommended because these species used are the only predominant native California intertidal plants.

Table 39

Summary of Vegetation Data Collected at the Salt Pond #3 Field Site in 1986

Parameter	Density Stem/sq m	Stem Height cm	Frequency of Occurrence %	Flowering Stems/sq m
Planted intertidal zone				
Pacific cordgrass	176.4	94.0	100.0	110.0
Pacific glasswort/pickelweed	59.3	50.1	100.0	--
Mean percent cover = 87.0%				
Planted high marsh				
Pacific cordgrass	2.2	37.6	25.0	0.0
Pacific glasswort/pickleweed	523.7	44.9	100.0	--
Mean percent cover = 80.6%				
Means for both planted marshes				
Pacific cordgrass	134.7	89.1	70.0	63.9
Pacific glasswort/pickleweed	302.8	46.1	100.0	--
Mean percent cover = 83.4%				

PART XII: MILLER SANDS ISLAND, COLUMBIA RIVER, OREGON

Background

273. The Miller Sands Island (MS) habitat development site is a large, horseshoe-shaped dredged material island in the freshwater intertidal reach of the Columbia River, 8 km upriver from Astoria, OR, and within the Lewis and Clark National Wildlife Refuge (Figure 29). The original island was built in 1932, and it had been used for subsequent dredged material placement during maintenance dredging operations about every 4 years.* Since the eruption of Mount Saint Helens volcano, the large sand spit shown in Figure 30 on the north side of the island has been used for dredged material placement every year.

274. Vegetation, soils, fish, and wildlife found at MS prior to 1974 were relatively typical of river islands in the MS vicinity, where the upland areas are characterized by sandy soils of low fertility, and 2.4-m tides greatly influenced the shorelines and marshes. Typical wetland vegetation of spikerushes, Lyngbye's sedge and other sedges, tufted hairgrass, seaside arrowgrass, and several species of willows occurred in more protected coves in the river. Large numbers of Pacific Flyway migratory and overwintering waterfowl and shorebirds used the waters and mud flats in the MS area.

275. The MS site was selected for study during the DMRP because it was representative of a large, sandy dredged material island in the Pacific Northwest where multiple habitats could be developed and tested. The MS site was also a cooperative effort among several agencies and organizations, although it was entirely funded by the CE. Site engineering, dredging, and elevational grading on the sand spit were accomplished by Portland District. Long-term monitoring was coordinated and conducted by the EL at WES. Since 1974, some site studies were contracted to Coastal Ecosystems Management Inc., NMFS, Wave Beach Grass Nursery, Woodward-Clyde Associates Inc., Oak Ridge National Laboratory, Mr. Jack Rogers (trapper), Oregon State University, Washington State University, Louisiana State University, and to Dr. Jack Crawford (private consultant).

* USAED, Portland, 1988, "Draft Long-Term Management Strategy for the Lower Columbia River, Oregon and Washington," Portland, OR.

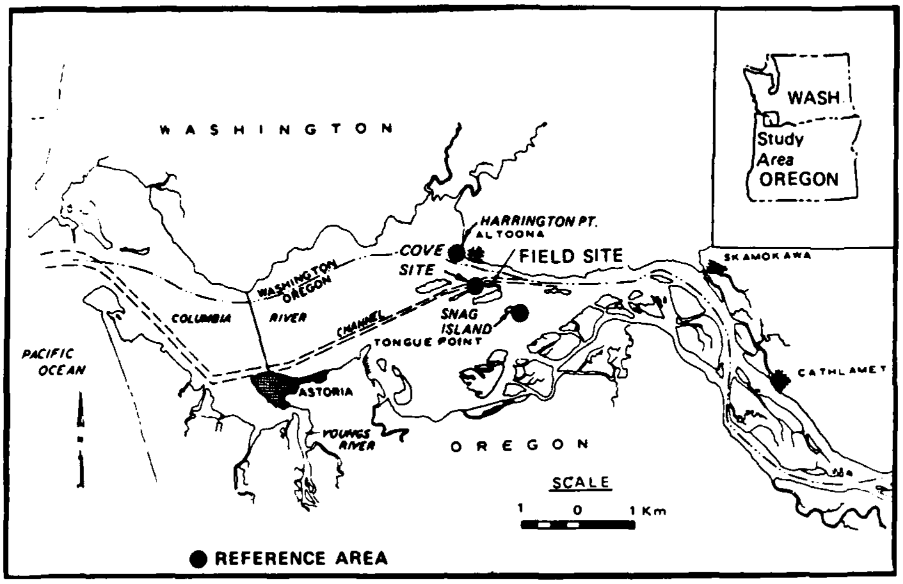

Figure 29. The MS field site in the lower Columbia River, Oregon

Figure 30. Miller Sands, showing the older main island and the sand spit that were developed as wetland, upland meadow, and dune habitats

276. Long-term objectives for the MS site were to (a) develop wetland, upland, and dune habitats on the island complex; (b) document the successional changes and success of these efforts; and (c) develop and demonstrate techniques and methods for large-scale habitat development projects. Numerous WES technical reports and papers have been written on the MS site documenting in detail the habitat development effort* (Cutshall and Johnson 1977; Clairain et al. 1978; Crawford and Edwards 1978; Heilman et al. 1978; McConnell et al. 1978; Ternyik 1978; Woodward-Clyde Consultants 1978; Newling and Landin 1985; Landin, Newling, and Clairain 1987).

Site Development

1974-1978

277. Three habitats were developed at MS, an upland habitat on the main island, a wetland between the sand spit and the main island, and dune plantings on the sand spit to provide protection to the planted wetland from wind erosion. In 1974-1975, the interior cove of the sand spit was graded to an intertidal elevation with a dozer, while the upland portion of the main island was being disked and a seedbed prepared with heavy range equipment and farming implements. The three planting operations were carried out by Wave Beach Grass Nursery and are briefly described as follows.

278. Vegetation. The outer portions of the sand spit were planted with sprigs of European beachgrass alternated with rows of wooden sand/snow fence in 1977. This planting effort resulted in almost immediate dune formation (by 1978) that has remained in place throughout the entire 14 years of study.

279. So little was known about the potential for establishing Pacific Northwest marsh species on man-made sites that a small pilot study was conducted in the cove to determine which species would offer the best chance

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* J. A. Crawford and D. L. Dorsey, 1979, "An Evaluation of Avian Populations on Dredged Material and Undisturbed Island Habitats," Unpublished Report, Portland, OR.

P. E. Heilman, 1979, "Investigation of Vegetation and Soil Sediments on the Planted Marsh at Miller Sands and on Nearby Natural Marshes in the Columbia River Estuary," Unpublished Technical Report prepared for WES, Vicksburg, MS, by Washington State University, Pullman, WA.

M. K. Johnson, 1980, "Analysis of the Botanical Composition of Nutria Stomach Contents from Miller Sands Island, OR," Unpublished Technical Report prepared for WES, Vicksburg, MS, by Mississippi State University Department of Wildlife and Fisheries, Mississippi State, MS.

of success. Eight species were selected from those tested and were planted in experimental plots in the cove. These species were tufted hairgrass, Lyngbye's sedge, blue flag, broadleaf arrowhead, soft rush, American three-square, and water plantain. These plants were chosen for their wildlife food values as well as their ability to stabilize wetland soil. Tufted hairgrass and slough sedge were planted in monotypic plots, and all eight species were tested in mixed species plots. Fertilizer was tested at various levels, but was found to have no long-range effect on plant survival in the wetland area.

280. By 1978, plants had spread beyond their original plots and had generally vegetated the entire planted area. All species survived and were present at varying levels at the end of the DMRP, but the most rapid growth, survival, and reproduction were by slough sedge, tufted hairgrass, and Lyngbye's sedge.

281. The large open area on the 94.7-ha main island was disked, fertilized, and planted in large test plots as a nesting and feeding meadow for waterfowl, primarily Canada geese. Seed mixtures of native red clover, white Dutch clover, hairy vetch, barley, tall wheatgrass, Oregon bentgrass, reed canarygrass, red fescue, and tall fescue were planted in 1976. Test plots were either treated with various fertilizer levels or untreated as control plots.

282. Seven of these meadow species initially established well; red fescue and reed canarygrass did not survive. All treated plots of these seven species showed an initial response to fertilizers regardless of level of application. The dredged material soil of the older main island was very sandy and infertile, so this was an expected occurrence. By 1977, the rush of new, vigorous growth had slowed in the meadow, and the fertilizer amendments were exhausted. Also by 1977, invasion of test plots by scouring rush, common velvetgrass, and rattail fescue occurred, and the hairy vetch developed black rust stem disease that affected its survival.

283. Soils. In soils analyses prior to 1978 (Heilman et al. 1978), elevation was found to be a key factor affecting soil fertility and soil chemistry. In the planted wetland at the lowest intertidal level, exchangeable potassium, phosphorus, ammonium nitrogen, total nitrogen, organic carbon, and cation exchange capacity were highest and decreased with elevational changes across the marsh. Fertilizer applications lowered pH, but increased nitrogen, phosphorus, potassium, and percent carbon in the meadow, but not

significantly. These influences of fertilizer began decreasing within 3 months of application.

284. Benthic and fisheries analyses. Predevelopment and post-development surveys of benthos and fish around the MS site were made using a variety of techniques and equipment (McConnell et al. 1978). Results showed that site construction and planting activities had no effect on either species abundance or diversity. Of the 21 fish species caught at MS, most abundant were chinook salmon, peamouth, starry flounder, and threespine stickleback.

285. Benthos at MS was overwhelmingly dominated by *Corophium salmonis*, oligochaetes, chironomid larvae, and Asiatic clams and compared well with a nearby reference marsh that was also sampled. Through 1977, the benthic and fisheries communities remained relatively unchanged in species diversity or abundance. By 1980 at the next intensive sampling period, there had been significant changes in benthos species composition but not abundance.

286. Wildlife. Early (1974-1977) wildlife surveys at MS are detailed in Clairain et al. (1978), Crawford and Edwards (1978), and Woodward-Clyde Consultants (1978), and summarized as follows. Prior to 1975, 65 bird species were observed at MS; 55 percent of these were waterfowl, shorebirds, and songbirds. Six species nested on the island prior to development, with all species use closely related to the habitat diversity provided by the main island, the sand spit, and the enclosed mud flats. Through 1977, 108 bird species were observed on MS; 81 percent were waterfowl, shorebirds, and songbirds. Canada and snow geese fed in the planted meadow, mallards nested in it, and swallows in large numbers fed on flying insects there. Nine nesting species were found during this period.

287. Six mammal species were found prior to MS habitat development; seven were found through 1977. The overwhelmingly dominant mammals were nutria and Norway rats that fed over the entire island. From 1975 through 1978, 774 nutria were trapped and removed from MS, and another 729 were removed from nearby islands; 145 Norway rats were also removed from MS. The other five mammals sighted occurred in low numbers: Townsend's vole, Trowbridge's shrew, deer mouse, harbor seal, and muskrat. Mammal populations at MS appeared to be skewed towards species that could reach an island in the middle of a large dynamic river, either from ships (Norway rats), on driftwood (voles, shrews, and mice), from shoreline marshes (nutria and muskrat), or from the sea (harbor seals).

288. There was an initial increase of insect abundance after the MS wetland was planted, but an insect biomass decrease followed after preparing a seedbed and planting the meadow. In a final insect sampling in July 1977, insect levels in the meadow were still slightly below unplanted grassy areas on the MS upland areas.

1979-1982

289. Midphase long-term monitoring data for MS are detailed in Newling and Landin (1985) and Landin, Newling, and Clairain (1987) and summarized in this section. In this phase of site development, three nearby reference marshes were selected for comparison purposes to MS (Cove Site, Harrington Point, and Snag Island). There were no nearby upland or dune areas similar enough for comparison purposes. Heilman* documented soils and vegetation status in 1978, and in 1980 and 1982, intensive vegetation sampling occurred (Newling and Landin 1985). Crawford and Dorsey** conducted an intensive wildlife observation program on MS in 1978. The final benthic sampling took place in 1980, but was not continued because of manpower and budget constraints. No fisheries samples were collected after 1977 for the same reasons.

290. Vegetation. Transects with randomly selected quadrats were established on MS and the three reference marshes and were used for data collection in 1978, 1980, 1982, and subsequent later sampling. Details of sediment trapping, vegetation biomass and cover tables, and soils chemistry are presented in Newling and Landin (1985) and will not be repeated in this report. Findings indicated that the MS planted marsh was now higher in elevation from sediment accumulation than the reference marshes. The lower zone of the natural marshes tended to be common spikerush, a species that had invaded the MS site but that did not become dominant at MS throughout the study. Higher zone marsh plantings were not growing well, with slough sedge having died out altogether and tufted hairgrass growing poorly on these highest areas.

291. Several reasons for the changes in the wetland were observed and continued throughout the study. Sand accumulation from the continued dredging process that provided a ready source of blowing sand from the lower (unvegetated) portions of the sand spit took place, but no measurement of quantity

* Heilman, op. cit.
** Crawford and Dorsey, op. cit.

was attempted. Of more importance to the immediate change in the planted higher marsh was the encroachment of the dunes that had formed almost immediately upon planting of beachgrass and erection of sand fence. While these dunes have not crept into the intertidal zone itself (current and tidal erosion prevented this), they had a significant impact on vegetation in the high marsh and on the sand spit in general and were a feature that was not duplicated at the natural reference marshes. Beachgrass plantings on the sand spit began spreading almost immediately after initial establishment and by 1982 had colonized outer fringes of the sand spit nearly a mile downstream from the original plantings. In a belt transect sample of the planted dunes, greatest biomass and greatest seed production were always found to be at the dune crests and upper slopes, and dunes were observed to be the only factor on the upriver end of the spit that was preventing the sand spit from blowing and eroding away. Stem density per beachgrass plant had increased from 26.9 in 1977 to 87.5 in 1982, and flowering stems per plant from 0.4 in 1977 to 6.9 in 1982 (Newling and Landin 1985).

292. In comparison to the three reference marshes through 1982, MS showed less percent plant cover and biomass production, and an increase in organic carbon. This was especially evident at the higher marsh elevations that did not receive as great a tidal influence and nutrient influx, but were exhibiting high sediment trapping levels. By 1982, both tufted hairgrass and slough sedge had decreased in the planted high marsh zone, increased in the middle marsh zone, and appeared to be stable in the lower intertidal zone. Vegetation in the lower zone, while still being dominated by tufted hairgrass and Lyngbye's sedge, was a mixture of both planted and invading species such as water foxtail and yellow monkey flower and shaded into extensive mud flats, another feature that was also not present at the reference sites.

293. At least 55 plant species were recorded in the planted wetland at MS by 1982. Many of these had less than 1-percent relative frequency, although 24 commonly occurred across the marsh. The most common species by 1982 was tufted hairgrass; Lyngbye's sedge and slough sedge, while still important species in the marsh, appeared to be decreasing. Lyngbye's sedge and tufted hairgrass also produced more biomass than any other species (extensive biomass tables were published in Newling and Landin (1985)). Pointed rush, beggarticks, birdsfoot-trefoil, water foxtail, and yellow monkey flower were also common species. While MS had lower biomass productivity than the

three reference marshes, it was much more diverse, and also evolving and changing rapidly. Table 40 is a summary of vegetation data for 1982, 1984, and 1986 and gives stem height and density, frequency of occurrence, and flowering stems. In addition to the species listed on Table 40, some plant species observed in the MS wetland never occurred on transects. They are alsike clover, common forget-me-not, English plantain, purple loosestrife, water horehound, water parsnip, willow spp., and alder.

294. In transects with randomly selected quadrats on the upland meadow through 1982, stem density, stem height, frequency of occurrence, and flowering stems were recorded. Table 41 is a summary showing percent cover for 1980, 1982, and 1986 to give an indication of diversity and condition of the upland meadow over time.

295. By 1980, the upland meadow at MS was reverting to a dry, infertile, overgrazed (by nutria) upland. By 1982, scouring rush, cat's ear, and moss were reclaiming the upland, though the planted species of tall fescue, redtop, and red fescue were maintaining sparse stands and slowly increasing percent cover. White Dutch clover, western wheatgrass, Oregon bentgrass, barley, and native red clover were all but gone. Hairy vetch was gone by 1980, and reed canarygrass and red fescue that were thought not to have survived (were not found along transects or in plots through 1978) had established and gradually increased.

296. The meadow areas through 1982 decreased from a lush, fertilized, mixed species upland to a site impacted by the increasing rodent population. Trapping had ceased on MS and adjacent islands at the end of the DMRP, and overgrazing was extremely evident. The exclosures that had been built in the wetland and upland at MS in 1975 were mostly intact and made the evidence of overgrazing all the more dramatic. Inside the cages, remnant stands of the planted grasses and forbs survived, while outside the cages, the predominant vegetation was scouring rush and less edible vegetation. Although grazing was evident and extensive in the wetland area, the more rapid growth, the plant species occurring, and the nutrient influx into the system greatly lessened that impact.

297. The stomach contents of 14 trapped nutria at MS were analyzed to determine what they had grazed,* and sedges, particularly Lyngbye's sedge,

* Johnson, op. cit.

Table 40

Summary of Vegetation Data at MS Wetland in 1982, 1984, and 1986

Species	Stem/sq m Stem Density			Stem Height, cm			Frequency of Occurrence, %			Flowering Stems No./sq m		
	1982	1984	1986	1982	1984	1986	1982	1984	1986	1982	1984	1986
Beggarticks	12	15.2	14.9	15.7	15.1	16.3	75.0	75.0	82.5	0.0	0.0	0.0
Birdsfoot-trefoil	5.8	4.9	5.1	53.0	52.5	54.8	37.5	25.0	37.5	2.0	0.5	1.0
Common spikerush	0.2	0.1	1.0	60.0	58.5	61.5	12.5	25.0	25.0	0.0	0.0	0.0
Douglas aster	3.0	5.5	4.8	64.0	70.0	67.5	62.5	50.0	75.0	0.0	0.0	0.0
Flowering quillwort	1.0	0.5	0.3	5.0	4.8	5.1	12.5	6.3	12.5	0.0	0.0	0.0
Blue flag	138.5	127.8	134.5	9.7	10.9	10.3	100.0	87.5	100.0	0.2	3.0	3.5
Lyngbye's sedge	17.0	22.5	23.5	94.7	92.8	99.3	37.5	50.0	50.0	1.3	2.5	2.0
Pacific silverweed	1.2	0.1	0.5	13.4	15.6	14.5	25.0	6.3	12.5	0.0	0.0	0.0
Pointed rush	9.5	12.0	10.5	64.8	70.3	69.5	50.0	50.0	62.5	10.0	7.8	11.5
Reed canarygrass	1.3	2.5	2.0	106.2	115.4	112.9	25.0	12.5	25.0	0.8	2.5	3.8
Slough sedge	2.2	10.5	6.3	87.1	90.3	92.5	12.5	12.5	6.3	0.0	1.0	0.0
Smartweed spp.	5.0	9.6	12.5	13.6	18.4	22.0	75.0	87.5	100.0	0.0	0.0	0.0
Spring water starwort	0.5	0.0	0.0	19.0	0.0	0.0	12.5	0.0	0.0	0.2	0.0	0.0
Tapered rush	1.0	0.3	0.0	68.2	70.4	0.0	12.5	12.5	0.0	0.8	0.2	0.0
Tufted hairgrass	399.8	426.3	412.6	130.9	150.3	149.2	100.0	100.0	100.0	55.0	67.5	65.3
Water foxtail	250.0	238.9	265.8	40.7	47.3	45.1	75.0	87.5	87.5	0.0	0.0	0.0
Watson's willow-herb	3.8	9.3	4.5	67.2	60.3	71.4	87.5	100.0	87.5	0.0	0.0	0.0
Yellow monkey flower	10.5	15.8	14.7	55.3	56.9	53.4	100.0	100.0	100.0	0.0	9.5	5.8
Mean Percent Cover:	1982 = 82.1			1984 = 80.5			1986 = 78.9					

Table 41

Percent Cover for 1980, 1982, and 1986 on the Upland Meadow at MS Habitat Development Site

Species	Across Three Combined Meadows 1980	1982	1986
Barren bromegrass	0.1	0.0	0.3
Birdsfoot-trefoil	0.0	0.1	0.3
Canadian bluegrass	0.1	0.0	0.1
Cat's ear	0.1	2.2	2.0
Cheat grass	0.1	0.0	0.5
English plantain	3.1	1.4	2.0
Hop clover	0.0	1.3	1.6
Lichens	0.1	0.2	0.2
Mosses	14.4	30.2	29.6
Mouse-ear chickweed	1.0	0.0	0.3
Oregon bentgrass	1.3	0.0	2.0
Pearly everlasting	0.1	0.0	0.2
Rattail fescue	0.0	0.9	1.0
Native red clover	0.0	0.2	0.6
Red fescue	5.9	14.3	13.7
Red top	1.0	13.9	15.3
Reed canarygrass	2.8	2.2	2.4
Ryegrass	0.0	0.1	0.1
Scouring rush	9.3	13.9	10.4
Sheep sorrel	0.8	0.0	0.2
Sleepy catchfly	0.1	0.0	0.1
Stream lupine	4.0	1.8	2.2
Suckling clover	0.4	0.7	0.9
Tall fescue	6.7	9.4	10.6
Vetches	0.1	0.0	0.0
Western wheatgrass	0.7	0.0	0.0
White Dutch clover	0.3	0.0	0.1
Totals	52.1	92.7	95.7

were the most important foods taken by the nutria. Other contents were slough sedge (only available at the planted marsh), Douglas fir, vetch, grasses, smartweeds, and lesser amounts of a wide variety of plants available to them.

298. Benthos. Benthic samples at MS and the three reference marshes were collected in 1980, the last time benthos was sampled on the site. These were compared with data collected from 1975-1977 and are published in Newling and Landin (1985). A summary of findings indicates that all four sites were dominated by oligochaetes of the families Tubificidae, Lumbriculidae, and

Enchytraeidae. Oligochaetes comprised 67 percent of all individuals at MS, 80 percent at Cove Site, 89 percent at Harrington Point, and 93 percent at Snag Island. The other 24 species and groups occurred in much less abundance. Site variations included: (a) lymnaid snails were more abundant at MS, (b) sphaerid clams were abundant at Cove Site, (c) chrysomelid larvae were abundant at Harrington Point, and (d) chironomid larvae were abundant at Snag Island. Eight of the twenty-seven taxonomic groups occurred at only one of the four marshes, and there was much overlap in group composition of the four marshes. No taxa occurring at any one site made up more than half of the taxa at any other site. Each was very different.

299. *Corophium salmonis* was the predominant benthos at MS in 1976 but was virtually absent at MS in 1980. In fact, only five individuals were collected among the four marshes, so that the species appeared to be absent from the area. Asiatic clam populations found in 1976 in MS had also declined at MS and were present only in low numbers at the reference marshes, indicating considerable change in benthos in the region of MS. Elevational differences in occurrence and abundance were also noted and are detailed in Newling and Landin (1985). Evidence indicated that 4 years after planting, the MS site resembled its reference marshes in community structure although abundance of individuals was less than the older, undisturbed natural marshes.

300. Wildlife. Birds continued to be the predominant users of MS, and wildlife surveys from 1979-1987 recorded 112 bird species and 9 mammal species (Table 42). Wildlife use was different for MS and the reference areas. Birds using MS were more similar to Snag Island, which was also an old dredged material island. Birds and mammals using Harrington Point and Cove Site were similar because these were shoreline sites. Without exception, more species diversity and abundance were found on MS. More than twice as many bird species in greater numbers were found on MS as on any of the reference marshes, and over time, apparently the insular situation of MS was not a long-term deterrent to mammal colonization.

1983-1987

301. A number of events concerning MS occurred during this period, such as the severe drought that the Pacific Northwest experienced over a 2-year period that impacted the upland site and allowed greater saltwater intrusion into the river. Another event was that FWS personnel at the Lewis and Clark Refuge made low-level applications of fertilizer to the upland meadows at MS

Table 42

<u>Wildlife Observed at the MS Field Site, 1974-1987</u>

Alder flycatcher 4*	American coot 1
American crow 1,2,3,4	American goldfinch 2,3,4
American kestrel 1,2,3,4	American robin 3,4
American widgeon 1	Baird's sandpiper 1,2
Bald eagle 1,2	Barn swallow 1,2,3,4
Belted kingfisher 1	Bewick's wren 3,4
Black-bellied plover 1,2	Black-capped chickadee 3,4
Black-headed grosbeak 3,4	Black-throated gray warbler 3,4
Black turnstone 2	Bohemian waxwing 4
Boneparte's gull 1,2	Brown-headed cowbird 1,2,3,4
Bufflehead 1	California gull 1,2
Canada goose 1,2,3	Caspian tern 1,2
Cedar waxwing 4	Chestnut-sided warbler 3,4
Chipping sparrow 3,4	Cinnamon teal 1
Cliff swallow 1,2,3,4	Columbia white-tailed deer 1,2,3,4
Common loon 1	Common merganser 1
Common nighthawk 3	Common raven 2,3
Dark-eyed junco 3,4	Deer mouse 2,3
Double-crested cormorant 1,2	Downy woodpecker 4
Dunlin 1,2	Dusky flycatcher 3,4
Eared grebe 1	European starling 1,2,3,4
Fox sparrow 3,4	Glaucous gull 2
Glaucous-winged gull 1,2	Golden-crowned kinglet 4
Great blue heron 1,2	Greater scaup 1
Greater white-fronted goose 1,3	Greater yellowlegs 1,2
Green-winged teal 1	Gadwall 1
Great horned owl 3,4	Hermit thrush 3,4
Horned grebe 1	Horned lark 2,3
Harbor seal 2	Hutton's vireo 3,4
Killdeer 2,3	Lark sparrow 3,4
Least sandpiper 1,2	Lesser yellowlegs 1,2
Lewis' woodpecker 4	Long-billed dowitcher 1,2
Mallard 1	Marbled godwit 2
Marsh wren 1	Merlin 1,2
Mew gull 1,2	Mourning dove 3
Muskrat 1,2,3	Northern flicker 2,3,4
Northern harrier 1,2,3,4	Northern pintail 1
Northern rough-winged swallow 1,2,3,4	Norway rat 1,2,3,4
Nutria 1,2,3	Orange-crowned warbler 3,4
Peregrine falcon 1,2,3	Purple finch 3,4
Red-breasted sapsucker 4	Red knot 1,2
Red-tailed hawk 1,2,3,4	Red-throated loon 1
Ring-billed gull 1,2	Ruby-crowned kinglet 4

(Continued)

* Observations made in: 1 = marsh cove; 2 = sand spit; 3 = island meadow; 4 = tree/shrub upland.

Table 42 (Concluded)

Ruddy duck 1	Rufous hummingbird 4
Rufous-sided towhee 3,4	Sabine's gull 1,2
Sanderling 1,2	Savannah sparrow 2,3,4
Sea lion 2	Semipalmated plover 1,2
Short-eared owl 2,3	Snowy plover 1,2
Song sparrow 2,3,4	Swainson's thrush 3,4
Townsend's vole 2,3,4	Townsend's warbler 3,4
Tree swallow 1,2,3,4	Trowbridge's shrew 2,3
Tundra swan 1	Vaux's swift 1,2,3,4
Violet-green swallow 1,2,3,4	Warbling vireo 4
Water pipit 1	Western bluebird 3,4
Western flycatcher 2,3,4	Western grebe 1
Western gull 1,2	Western kingbird 2,3
Western meadowlark 1,2,3	Western sandpiper 1,2
Western wood-pewee 3,4	White-crowned sparrow 3,4
Willow flycatcher 3,4	Wilson's warbler 3,4
Winter wren 3,4	Yellow-breasted chat 3,4
Yellow warbler 3,4	

and other upland locations on their refuge in a low-level management effort, which influenced the upland vegetation.

302. Salmon fishermen increased their fishing efforts in the channel adjacent to the MS sand spit, and salmon buyers positioned their boats just off MS so that fishermen could offload their catches quickly. Sightings of harbor seals and sea lions increased, probably as a direct result of the salmon fishery, and bald eagles from 22 area nests fished in and around MS.

303. The upriver chute between the sand spit and the main island (Figure 29) that had once been shallow enough to walk across during site visits had eroded from both the sand spit bank and main island bank (undercutting established trees) and was now over 35 m wide and 3 to 5 m deep. Much of the planted marsh eroded because of increased currents through the chute. In 1988, during maintenance dredging of the channel, Portland District reclosed most of the eroded chute with sandy dredged material, leaving a small opening for flushing of the wetland that is expected over time to require continued management through dredged material placement.

304. The Portland District began development of a long-term dredged material management plan for the lower Columbia River, including MS, that will

be coordinated with concerned ports, users of the Columbia River Channel, and state and Federal resource and regulatory agencies.

305. Vegetation. Low-level vegetation sampling continued through 1986, in which stem height and density, frequency of occurrence, and flowering stems were recorded (Table 40). In 1983, 1985, and 1987, only qualitative data were collected. This involved visual estimates of change in vegetation, physical conditions such as erosion, grazing effects, wildlife, and environmental changes that could be observed in site visits. A very diverse plant community continued to occur at the MS wetland, but a number of physical changes had occurred in the marsh. When the chute widened between the sand spit and the main island, the marsh eroded from its lower edge. At the same time, more and more sand encroachment seemed to be occurring in the original high marsh area, so that it was almost entirely a transitional zone with some upland species occurring.

306. As a result of these changes, tufted hairgrass generally grew only in the middle elevational zone, and the mud flats expanded to cover what used to be the lowest planted zone at MS. However, tufted hairgrass continues to dominate the overall marsh, followed by Lyngbye's sedge, water foxtail, and beggarticks. Slough sedge was not found in any of the established transects, but was still occurring on MS as an incidental species. These trends and changes are reflected in Table 40. Yellow monkey flower and pointed rush were also still common in the MS wetland.

307. No additional plant species were found in the planted wetland. Plant cover and biomass production continued to be lower at MS than at the reference marshes, although Cove Site and Harrington Point had also both decreased in overall size and appeared to be higher in elevation than when originally surveyed in 1978. Sediment accumulation at all four sites was evident. At MS, accumulation could be attributed to continued deposition of dredged material; however, this source of material was not available to the three reference marshes. In spite of obvious elevational changes, common spikerush was still the dominant species in the reference marshes and was more common at MS, though not in the established MS transects.

308. At the MS meadow on the main island, a flush of growth of grasses and forbs was evident after FWS applied fertilizer to the site in 1985. In the first year, the fertilizer was enough to offset the effect of grazing animals, but without additional or annual fertilizer applications, the meadow

will continue to decline. Percent cover in Table 41 indicates the low level of vegetation within the established transects.

309. When the MS site was first selected for study, the main island had a fringe of trees ringing it, with isolated stands in low areas. This woody vegetation apparently had been present on the island since it first colonized after construction in 1932. However, since 1976, the trees and shrubs have encroached more and more into the meadow, so that visually the large expanses of meadow that were present in 1976 are broken up by trees. This encroachment is believed to be a result of the fertilizer applications and resultant additions of organic matter to the meadow area that have allowed woody species' seeds to germinate and survive in spite of the droughty conditions and have allowed existing trees to grow more vigorously.

310. Wildlife. The MS site, with its habitat diversity and insular location, continued to be overwhelmingly dominant in comparison to the three reference sites with regard to both wildlife abundance and diversity of species. A high percentage of the 112 bird species found on MS were waterfowl and shorebirds in the wetland and adjoining mud flat and sand spit, and songbirds on the main island. During migration, especially during the fall, tens of thousands of shorebirds feed along MS shorelines and marsh fringes. In summer months, mallards nest on MS. Canada geese, white-fronted geese, snow geese, mallards, pintails, gadwalls, American widgeon, redheads, greater scaup, and Barrow's goldeneye have all been sighted at MS in migration or overwintering.

311. Many of the songbirds on the main island are summer or year-round residents, and a number of them nest in and around the meadow. These include the species common crow, cedar waxwing, black-capped chickadee, savannah sparrow, song sparrow, tree swallow, white-crowned sparrow, willow flycatcher, yellow warbler, western wood peewee, and American robin. A thorough search for nests during summer months over the entire main island has not been conducted since 1978. Additional nesting species may be present in addition to the 11 listed above, such as the western bluebird, which has been sighted on the island in late summer months.

312. A colony of glaucous-winged and western gulls nested on the downriver (western) end of the sand spit. Although this part of the sand spit contains little vegetation, the gulls tend to nest around beachgrass and any other clumps of vegetation and driftwood they encounter. This colony has

grown in size over the past several years and has been highly successful. Glaucous-winged and western gulls are known to hybridize, and some of the birds in the colony appeared to be hybrids.

313. In addition to the nesting gull colony, in 1986 a colony of double-crested cormorants that used to nest on structures in the river moved their nest sites to the MS sand spit. These cormorants were nesting on the ground on raised nests and were increasing in numbers. This new colony raised the number of nesting species on MS to 14. As a part of the ongoing documentation for the lower Columbia River long-term management plan, Portland District is monitoring these colonies.*

314. None of the 22 bald eagle nests in the lower Columbia River were located on MS. However, the adult and subadult birds fed in and around the island. This was especially noticed during salmon runs, when the birds would feed along the sand spit shoreline on dead or dying salmon that had broken free from fishermen's nets. In addition to these resident populations, wintering bald eagles also frequented the area.

Long-Term Management Plans

315. With the development of the lower Columbia River long-term management plan, the MS site will continue to receive dredged material management attention that incorporates habitat development beneficial uses.** These efforts will primarily involve the wetland and sand spit nearest the ship channel and the placement of dredged material for habitat enhancement. However, as part of the overall plan, benthos and fisheries data are now (in 1988) being gathered by the NMFS under contract with the Portland District. The District will continue its wildlife surveys, especially raptor surveys documenting movement and nesting success of the bald eagle population in the lower Columbia.

316. The lower Columbia River long-term management strategy is a national demonstration program for the CE and will be used as a model for development of long-term management srategies in other Districts. Features of

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* Personal Communication, 1988, Mr. Goeff Dorsey, Wildlife Biologist, USAED, Portland, Portland, OR.

** USAED, Portland, op. cit.

the working long-term plan, such as interagency working groups, long-range disposal options and placement locations, overall natural resource considerations that include cumulative losses of habitats, and beneficial use of dredged material that offset disposal effects, will be tested to determine cost-effectiveness and feasibility.

Summary

317. The MS field site was developed from an existing dredged material island, and three habitats--wetland, upland meadow, and dune--were established. Predevelopment and postdevelopment data collection and long-term monitoring to determine success, test techniques, and methodologies, document changes over time on the island, and compare the site with natural reference sites were conducted from 1974 through 1987. Monitoring is continuing through Portland District's long-term management strategy for the lower Columbia River, which includes MS.

318. The three habitats were planted in 1975-1976, and all were initially established successfully. Over time, the stabilization effort on the sand spit with European beachgrass was judged to be highly successful, so much so that beachgrass was probably the only factor in holding back more severe erosion of the dredged material sand spit, and to the point that the dunes were encroaching on the high marsh zones of the planted marsh.

319. The wetland area was dominated by tufted hairgrass, with other common sedges and numerous invading species. Over time, planted species in the upper zone were replaced by invaders, and those of the lower zone became intertidal mud flat. Compared with three natural marshes, MS consistently was lower in biomass, but higher in species diversity. All four marshes trapped enough sediment during the study that it affected species composition.

320. The upland meadow was a densely growing, lush area when planted that declined over time because of dry, infertile soil conditions and grazing pressure of MS nutria populations. A supplemental fertilizer application in the early mid-1980s revitalized the meadow temporarily and also made it apparent that only active management of the meadow would keep it a functioning habitat. Remnant stands of all of the planted species except hairy vetch were still occurring on the upland in 1987, but the dominant vegetation outside of

exclosure cages was scouring rush, a plant inedible to nutria, muskrats, and other island herbivores.

321. Physical changes in the island such as erosion of the chute between the sand spit and main island and the need for sites to place dredged material were found to be compatible factors. When the eroded chute began to take out portions of the marsh, Portland District reclosed it with careful placement of dredged material to both nourish the adjoining mud flat and leave a small opening for flushing of the cove and marsh.

322. Benthic data indicated that the MS site was equal to that of three reference marshes. Wildlife data indicated that the MS site was used by more than twice as many bird species and more mammal species than any of the reference areas; 112 bird species, including 14 nesting species, and 9 mammal species were observed on MS.

PART XIII: CONCLUSIONS AND RECOMMENDATIONS

Conclusions

323. The long-term monitoring of these 11 habitat development sites built of dredged material was primarily undertaken to demonstrate that such habitat could be developed using dredged material substrates. Long-term monitoring was also undertaken to develop and test the techniques and methodology for building wetland, upland, island, and aquatic habitats. No attempt at site management of the seven original DMRP field sites was made, because the intention was to document what the habitats would become over time if left alone. It was obvious that active site management of the MS upland meadow and the diked wetland at WP would have enhanced their continued viability. However, their "failures" provided valuable information which has led to improved site designs and less likelihood of similar "failures" at other habitat development sites within the CE.

324. Over the past 14 years, each of these sites have been "successful" in its own way. The word "successful" is used with regard to site stabilization, the amounts and quality of wildlife and other habitats created, vegetation cover, and the other variables measured and discussed within this report and the prior reports on these sites. Since site development, each has uniquely developed. In this regard, no site could be compared with any other except its own natural reference sites, and each ultimately was treated as an entirely separate study with some successional and functional similarities that crossed all sites. Six sites have been outstanding successes (GI, MS, PM, BS, AB, and SP3). Even without site management, the SP3, BS, AB, and NI sites will continue as stable sites for the foreseeable future, although the NI site and the MS upland could both benefit from a low-level management program of periodic liming and fertilization of the existing meadow. As ongoing CDF islands, both GI in Mobile District and PM in Detroit District will be actively managed for decades to come. These two sites are part of long-term management plans, either in place or being finalized, that provide for continued habitat development and management as a part of CE operations. The MS site is now also a part of a long-term management strategy for the lower Columbia River that is being developed by Portland District and as such

will continue to be actively managed through dredged material placement, with strong environmental considerations.

325. For BP and SWP, problem identification and workable solutions have been a part of the sites' histories. At BP, erosion potential has been addressed by continued efforts to find low-cost methods for marsh development and shoreline stabilization. Marshes formed at this site also seem almost self-defeating in that they have trapped great quantities of sand from littoral drift that eventually affect marsh elevation and viability. At SWP, corrections in placement of the dredged material and movements of the dredge pipe have resulted in more than twice as much marsh created in 1986-1987 as in the previous 5 years. New Orleans District will continue with these marsh nourishment/development efforts through the building of more than 14,000 additional hectares of marsh using dredged material from the New Orleans Project and other Louisiana coastline areas.

326. At the LW and NI field sites, developed habitats progressed to conditions that, while not completely fulfilling the target habitat objectives, nevertheless are productive in their own way. At LW, St. Paul District is considering additional placement on the marsh island during the next dredging cycle in 1990 to increase the size, height, and diversity of the island. As an "old-field" meadow, NI receives much more wildlife use and has provided stability to a sandy dredged material deposit that did not previously exist. After 14 years, NI's reference sites are still partially vegetated sand mounds or disturbed island sites that could be dramatically improved by habitat development and low-level management.

327. The WP site had insurmountable problems that could not be overcome without intensive site management of the dredged material. The WP would probably also have greatly benefited from new applications of dredged material to nourish the existing marsh. However, it remained as its target habitat (freshwater, intertidal, emergent wetland) for 9 years before beginning to erode and remains as an emergent wetland/shallow water habitat that has potential for active management using dredged material.

328. Concerns expressed by regulatory and resource agencies as to whether man-made marshes function as natural marsh systems and have equal value as natural marshes over time have been addressed for these 11 sites. Data have been published in a series of 40 technical reports (including this report) answering these questions. Since there are extremely few new <u>natural</u>

marshes being formed in the United States because of shoreline development in US estuaries and sediment management and trapping by hundreds of reservoirs, man-made lakes, water diversion, and other structures, it is all but impossible to find new natural marshes to compare with new man-made marshes. Virtually no new natural marshes could be located in adjacent vicinities for comparison with the 11 field sites. Therefore, this long-term monitoring effort has required the comparison of new man-made marshes with reference sites that often were hundreds of years old.

329. Over the 14 years for the 7 original sites, a total of 27 reference sites were selected and sampled during various phases of this project. In spite of having to use reference sites that had been evolving for many years for comparison, the developed wetlands at WP (before 1984), MS, BS, AB, and SP3 in comparison with their 18 reference sites have proven to be at least:

a. Comparable in many respects (benthos, fisheries, vegetation aboveground biomass, stem height, and seed production).

b. Evolving over time to being similar to natural systems (soils, vegetation belowground biomass and percent cover).

c. Better (wildlife, plant vigor and growth, and overall greater marsh diversity and greater species composition) than their reference sites.

The marshes at BP have been lower in vegetation parameters than two of its reference sites and equal to another, but through the conclusion of aquatic studies in 1980 had not evolved to match benthos and fisheries abundance at its much older reference marshes. The seventh site, NI, was entirely an upland project, and no wetland comparisons were made. However, compared with its reference sites, it was found to be more productive by far in vegetation, wildlife, soils, and every other parameter measured.

330. The creation of or provision for tidal creeks and channels at several sites (MS, SP3, AB, and SWP) and of a containment pond at GI have increased aquatic habitat diversity. If the measure of a good marsh, as some resource agencies have stated, is whether it functions as benthic and fisheries habitat, then the marshes built by the CE as demonstration sites have measured relatively well against these criteria. Since the CE also considers a marsh to be successful if it also provides long-term stability, hurricane and storm protection, water quality improvements, and shoreline and overall site protection and/or increases overall marsh habitat within an

estuary, lake, or river, these criteria were also examined, and CE demonstration marshes have also measured well in most cases. It is important to remember that all wetland systems are different, and all sites' objectives will not be and should not be the same. It is also important to remember that a marsh serves many functions that do not necessarily involve providing benefits to adjoining aquatic systems, although this is a primary function.

331. Results of these studies have not been held until the conclusion of long-term monitoring, and data on benthos, fisheries, soils, vegetation, water quality, contaminants, wildlife, and physical and environmental successional changes have been published for use by CE personnel and other interested groups who were considering habitat development as a part of their project activities. As a result of this important technology transfer, there are numerous examples of CE habitat development on dredged material other than these 11 sites. They range from island and wetland habitats in Chesapeake Bay to emergent marsh in Mississippi Sound; to intensively used bird nesting islands in 16 Districts; to salmon habitat enhancement in Washington State and Vancouver, British Columbia; and to multipurpose sites incorporating habitats, recreation, and commercial uses in Oregon, Michigan, Ontario, Texas, and Florida.

332. This technology has been developed and applied in field tests for the construction and development of ecological habitats using dredged material. It can be applied to numerous other situations such as for constructed wetlands for Section 404 mitigation or compensation. This technology can be used for certain endangered species habitat development and protection, for colonial bird-nesting habitats, and for applying low-cost, low-maintenance specifications in projects. Finally, it can also be used for direct application or modification for shoreline protection and erosion control, for sand dune stabilization, and for repair of problem areas such as sand blowouts, track damage, spot erosion, upland and wetland restoration, and otherwise disturbed or damaged habitats.

Recommendations

333. There are a number of recommendations for habitat development on dredged material that are detailed in the following paragraphs. In addition,

each dredged material site and project will have specific needs that may require special considerations.

334. Habitat development should be considered in projects, even if the dredging work has already taken place or the habitat development is to be on an existing dredged material site where new applications of dredged material are to be applied. This also applies even if the habitat development is to be carried out by other than dredging methods (marsh topsoil relocation, fill of an eroding upland, abandoned mine reclamation, strip mine restoration or other situations where dewatered, stockpiled dredged material is hauled for reuse.

335. Nearby sites in the project vicinity should be examined to determine habitat needs and the likelihood of construction success. This includes evaluation of any critical habitats and endangered species in the vicinity of the project. For realistic site success, it also includes examination of physical and chemical characteristics such as potential or existing location in relation to the type of habitat desired; the type of dredged material available for construction; currents or tides, or both, that will impact the project site; and long wind fetches, especially those coupled with shallow bay or estuary conditions.

336. As with any biological or agricultural project, site variables must be taken into account, and allowance must be made for some margin of error. This is especially so when the site is subject to severe storm action, subsidence, strong river or lake currents, or long wind fetches. It also applies when the site construction material is of a fine-grained dredged material where there will be consolidation, settling, and other factors normal to silt/clay soils. If a wetland is planned, correct elevation of the site after consolidation and settling is absolutely critical.

337. If a project is to include habitat development or other natural resource beneficial uses (recreation, boating, outdoor trails, etc.), a set of criteria and objectives should be developed where these goals are included during project early planning stages. Criteria and objectives should be followed as closely as possible through construction, initial development, and some period of follow-up (long-term) monitoring by data collection and site evaluation. In some large projects, habitat development may be only one of the beneficial uses made of the dredged mat rial (PM is a good example of this).

338. Because a site may develop over time into a similar but equal habitat, a contingency management plan that allows for evolution of alternate habitats on the dredged material site should be developed. Such development should not automatically be ruled a failure without evaluation of the new situation. For example, the expected tree/shrub upland at BP instead evolved into a saltmeadow cordgrass/mixed forb high marsh. High marsh is a desirable habitat in Galveston Bay, and therefore, the "failure" of the upland plant community actually achieved a stable high marsh of equal value. The same case could be made for WP, where the expected emergent wetland after 9 years eroded into a combination emergent wetland and where shallow water/mud flat habitat could include everything from placement of additional dredged material to raise elevations or slow down erosion, to the removal of invading weedy plant species that are crowding out desired habitat by mechanical or chemical means or by controlled burning. It could also include removal of invading ground predators such as raccoons and coyotes that feed on eggs and chicks of nesting waterbirds on dredged material islands.

339. Careful instruction should be provided to dredging inspectors whose responsibilities include seeing that elevational and dredge pipe movement specifications are exactly fulfilled, and projects must be followed up to be sure that they are completed as specified. This is extremely critical in wetland construction work using unconfined dredged material, such as the SWP project. The dedicated and careful work of the dredging inspectors in Mobile District at GI and in Charleston District at a large unconfined wetland construction project in Winyah Bay, South Carolina, have been invaluable to the amounts and quality of the habitat built. Wilmington District has published an environmental guidebook for their dredging inspectors to assist them in making decisions regarding movement and placement of dredged material in North Carolina estuaries, where every coastal waterbird colony except one is located on CE dredged material islands.

340. Funding as well as authorization for habitat development activities that accompany District operations and maintenance dredging work should be examined. While authority exists for beneficial uses to be included in dredging projects under PL 99-662 and PL 94-587, CE operations and maintenance dredging projects must still operate under a fiscal management policy of "the least cost alternative that is environmentally acceptable." There are numerous examples where habitat development in conjunction with a project

actually saves costs to the project, especially if expensive transport of dredged material over long distances is eliminated or if habitat development eliminates expensive real estate acquisitions for disposal facilities.

341. Where habitat development can be done within the financial framework of the project or where it saves the project money, it is widely accepted as a dredging alternative. Where habitat development may be an attractive alternative, but may add slightly to the cost of the project, it may be much more difficult for CE personnel to win acceptance of that alternative. Funding limitations also influence the choices of habitat types selected within a project framework, because one use of the dredged material may be more expensive than another. With project cost-sharing under PL 99-662, habitat development costs will be shared by those sponsors, who will have a voice in how their funds are expended. Many of these sponsors prefer to have the dredged material from their channels put to beneficial uses, even if they have to cover reasonable additional costs.*

342. Physical and environmental monitoring of habitat development projects is necessary to determine success or failure. In other words, if habitat development or natural resources criteria are critical to project accomplishment, monitoring should be considered. A chronology of site construction and development and other measurements taken during the course of a project will help determine project success. Monitoring should be designed for a project's specific objectives established at the beginning of the project. This is especially so in habitat development projects or any project where environmental impacts are likely. Predevelopment, during development, and postdevelopment monitoring is recommended to determine what was there to be displaced or enhanced, what happened to it during dredging, and how it was improved or hurt by the habitat development or other beneficial use that followed.

343. Most CE projects provide for limited or no monitoring of environmental characteristics except water quality, contaminants, and aquatic impacts, and this monitoring is expected to occur briefly before and during dredging. Impacts on upland and wetland organisms, physical site characteristics, and changes to sites and their biotic communities over time are

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* Personal Communication, 1988, Mr. Richard F. Gorini, Environmental Coordinator, Port of Houston, TX.

generally not funded at levels to allow adequate documentation. If habitat development is critical to project success, provisions that allow Districts to include monitoring would be highly beneficial to the CE. It would greatly increase the expediency and acceptability it finds among resource and regulatory agencies and the general public in carrying out its dredging responsibilities.

344. Long-range management plans must be developed for dredging and placement that incorporates beneficial uses. Long-term plans that spell out goals and objectives over time in projects and that lay out some ecological and realistic approach to dredged material placement and management have been developed in several Districts for certain sites. Wilmington District developed a waterbird management plan using dredged material in the Cape Fear River in the mid-1970s. A long-range plan for PM in Detroit District was developed by 1979. Long-term management strategies (LTMS) for dredging regions are being developed now for Chesapeake Bay, the lower Columbia River, and large sites such as GI and Craney Island in Norfolk, VA. Planning and implementation of LTMS include coordinating an interagency working group to note ideas and potential conflicts. The LTMS concept in relation to natural resources and habitat development also addresses cumulative losses of habitats (especially wetlands), saves project funding, decreases project delays, and obtains long-term permits from regulatory agencies.

345. Numerous recommendations are itemized and discussed in Environmental Laboratory (1978), the WES guidance report on wetland habitat development, and in US Army Corps of Engineers (1986), the engineer manual on beneficial uses of dredged material that encompasses wetland, island, upland, and aquatic habitats and a wide range of other beneficial uses of dredged material, including recreation, agriculture, commercial and industrial, and multipurpose uses. These include such things as recommended species for certain types of habitats and types of soils, propagation and planting methods, engineering design and construction of sites, estimated costs, and site-specific considerations. These two reference documents should be considered companions to this final report on the long-term monitoring of CE habitat development field sites.

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APPENDIX A: PLANT AND ANIMAL COMMON AND SCIENTIFIC NAMES

Common Name	Scientific Name
Plants	
Alder	*Alnus* spp.
Alligator weed	*Althernanthera philoxeroides*
Alsike clover	*Trifolium hybridum*
American beachgrass	*Ammophila breviligulata*
American elm	*Ulmus americana*
American germander	*Teucrium canadense*
American searocket	*Cakile edentula*
American sycamore	*Platanus occidentalis*
American three-square	*Scirpus americanus*
Annual glasswort	*Salicornia biglovii*
Annual saltmarsh aster	*Aster subulatus*
Apple	*Malus pumila*
Arrow arum	*Peltandra virginica*
Arrowheads	*Sagittaria* spp.
Arrow-leaved tearthumb	*Polygonum sagittatum*
Asiatic bittersweet	*Celastrus crbiculatus*
Asparagus	*Asparagus officinale*
Asters	*Aster* spp.
Bagpod	*Sesbania vesicaria*
Bahia grass	*Paspalum notatum*
Baldcypress	*Taxodium distichum*
Barberry	*Berberis* spp.
Barley	*Hordeum vulgare*
Barnyard grass	*Echniochloa crusgalli*
Barren bromegrass	*Bromus sterilis*
Bayberry	*Myrica pennsylvanica*
Beach morning glory	*Ipomoea stolonifera*
Beach panic grass	*Panicum amarulum*
Beach-tea	*Croton punctatus*
Beardgrass	*Andropogon* spp.
Beech	*Fagus grandifolia*
Beggarticks	*Bidens* spp.
Big cordgrass	*Spartina cynosuroides*
Bigelow's glasswort	*Salicornia bigelovii*
Big smartweed	*Polygonum pennsylvanicum*
Bindweed	*Convolvulus* spp.
Birdsfoot-trefoil	*Lotus corniculatus*
Bitter mint	*Mentha canadensis*
Bitter panic grass	*Panicum amarum*
Black birch	*Betula lenta*
Black cherry	*Prunus serotina*
Black cottonwood	*Populus trichocarpa*
Black gum	*Nyssa sylvatica*
Black needlerush	*Juncus roemerianus*
Black oak	*Quercus velutina*
Black swallowwort	*Cynanchum nigrum*
Black willow	*Salix nigra*

Bladderwort	*Utricularia* spp.
Blazing star	*Liatris* sp.
Blue curl	*Trichostema dichotomum*
Blue flag	*Lilaeposis occidentalis*
Bluegrass	*Poa* sp.
Blue jointgrass	*Calamagrostis* sp.
Blue jointstem	
Big bluestem	*Andropogon perangustatus*
Blue vervain	*Verbena hastata*
Boneset	*Eupatorium perfoliatum*
Box elder	*Acer negundo*
Bracken fern	*Pteridium aquilinum*
Broadleaf arrowhead	*Sagittaria latifolia*
Broadleaf cattail	*Typha latifolia*
Brome grass	*Bromus* sp.
Broom sedge	*Andropogon virginicus*
Browntop millet	*Panicum miliaceum*
Bull thistle	*Cirsium vulgare*
Bull tongue	*Sagittaria lancifolia*
Bur cucumber	*Sicyos angulatus*
Burdock	*Arctium* sp.
Burreed	*Sparganium* sp.
Bushy beardgrass	*Andropogon glomeratus*
Buttercup pennywort	*Hydrocotyle ranunculoides*
Butterfly bush	*Buddleia alterniflora*
Butterfly weed	*Asclepias turberosa*
Buttonbush	*Cephalanthus occidentalis*
Cabbage palm	*Sabal palmetto*
Camphorweed	*Heterotheca subaxillaris*
Camphorweed fleabane	*Pluchea camphorata*
Canada thistle	*Cirsium canadensis*
Canadian bluegrass	*Poa compressa*
Cat's ear	*Hypochaeris radicata*
Cattails	*Typha* spp.
Centipede grass	*Eremochloa ophiuroides*
Cheat grass	*Bromus tectorum*
Chufa	*Cyperus esculentus*
Chinese tallow	*Sapium sebiferum*
Cinquefoil	*Potentilla* spp.
Clammy hedge hyssop	*Gratiola neglecta*
Climbing hempweed	*Mikania scandens*
Clovers	*Trifolium* spp.
Club moss	*Lycopodium* sp.
Coarse nutsedge	*Cyperus odoratus*
Coarse rush	*Juncus biflorus*
Coastal dropseed	*Sporobolus virginicus*
Coastal panic grass	*Panicum* sp.
Coastal sedge	*Carex exilis*
Cocklebur	*Xanthium sturmarium*
Colorado river hemp	*Cannabis* sp.
Common alder	*Alnus serrulata*
Common burdock	*Arctium minus*
Common Bermuda grass	*Cynodon dactylon*

Common crabgrass	*Digitaria sanguinalis*
Common elder	*Sambucus canadensis*
Common forget-me-not	*Myosotis scorpioides*
Common greenbrier	*Smilax bona-nox*
Common mullein	*Verbascum thapsis*
Common plantain	*Plantago virginica*
Common purslane	*Portulaca grandiflora*
Common ragweed	*Ambrosia artemisiifolia*
Common reed	*Phragmites australis*
Common spikerush	*Eleocharis palustris*
Common velvetgrass	*Holcus lanatus*
Coontail	*Ceratophyllum* sp.
Cowpea	*Vigna* sp.
Crabgrass	*Digitaria sanguinalis*
Croton	*Croton punctatus*
Curly-leaf dock	*Rumex crispus*
Cutgrass	*Leersia* sp.
Cypress bulrush	*Scirpus cyperinus*
Cypress spurge	*Euphorbia* sp.
Dallis grass	*Paspalum dilatatum*
Dandelion	*Taraxacum officinale*
Dayflower	*Commelina* sp.
Deer pea	*Vigna luteola*
Deertongue grass	*Panicum clandestinum*
Densely-flowered smartweed	*Polygonum clandestinum*
Dock	*Rumex* spp.
Dodder	*Cuscuta* spp.
Dog fennel	*Eupatorium capillifolium*
Douglas fir	*Pseudotsuga menziesii*
Douglas aster	*Aster subspictus*
Downy chess	*Bromus secalinus*
Dropseed grass	*Sporobolus* sp.
Drummond sesbania	*Sesbania drummondii*
Duckweeds	*Lemna* spp.
Dwarf dandelion	*Krigia virginica*
Eastern baccharis	*Baccharis neglecta*
Eastern cottonwood	*Populus deltoides*
Eastern red cedar	*Juniperus virginiana*
Elderberry	*Sambucus callicarpa*
English plantain	*Plantago lanceolata*
Eurasian watermilfoil	*Myriophyllum* sp.
Eurpoean beachgrass	*Ammophila arenaria*
Evening primrose	*Oenothera biennis*
Everlasting	*Gnaphalium* sp.
Fall panic grass	*Panicum dichotomiflorum*
False indigo-bush	*Amorpha fruticosa*
False nettle	*Boehmeria cylindrica*
Fescue	*Festuca* spp.
Field horsetail	*Equisetum arvense*
Field mint	*Mentha arvensis*
Field thistle	*Cirsium discolor*
Fimbristylis	*Fimbristylis castanea*
Fleabanes	*Erigeron* spp.

Floating-leaf pondweed	*Potamogenton natans*
Flowering quillwort	*Lilaea scilloides*
Flowering rush	*Butomus umbellatus*
Flowering spiderwort	*Tradescantia* sp.
Forget-me-not	*Myosotis* sp.
Four o'clock	*Mirabilis* sp.
Foxtail grass	*Setaria* sp.
Frankenia	*Frankenia grandifolia*
Giant cutgrass	*Zizaniopsis miliacea*
Giant reed	*Calamagrostis gigantea*
Glassworts	*Salicornia* spp.
Globe nutsedge	*Cyperus globosus*
Goldenrods	*Solidago* spp.
Goosefoot	*Chenopodium* sp.
Goose grass	*Eleusine indica*
Grape vines	*Vitis* spp.
Green ash	*Fraxinus pennsylvanica*
Greenbrier	*Smilax* sp.
Ground nut	*Apios americana*
Ground pine	*Lycopodium obscurum*
Groundsel	*Baccharis pilularis*
Groundsel tree	*Baccharis halimifolia*
Gulf cordgrass	*Spartina spartinae*
Gulf croton	*Croton* sp.
Gumweed	*Grindelia squarrosa*
Hairy vetch	*Vicia villosa*
Halberd-leaved tearthumb	*Polygonum arifolium*
Hawthorn	*Crataegus* sp.
Hedge mustard	*Sisymbrium officinale*
Hedge bindweed	*Convulvulus sepium*
Heliotropes	*Heliotrope* spp.
Hop clover	*Trifolium agrarium*
Horse nettle	*Solanum carolinense*
Horsetail fleabane	*Erigeron canadensis*
Ice plant	*Mesembryanthemum nodiflorum*
Indian blanket	*Gaillardia pulchella*
Indian hemp	*Apacunum cannabinum*
Ironweed	*Vernonia noveboracensis*
Ivy-leaved morning glory	*Ipomoea hederacea*
Japanese pittisporum	*Pittisporum tobira*
Jewelweed	*Impatiens capensis*
Johnson grass	*Sorghum halepense*
Knotgrass	*Polygonum aviculare*
Knotroot bristlegrass	*Setaria geniculata*
Knotweed	*Polygonum* spp.
Ladina white clover	*Trifolium repens ladina*
Lambsquarters	*Chenopodium album*
Late flowering thoroughwort	*Eupatorium serotinum*
Lead plant	*Amorpha herbacea*
Leafy beggarticks	*Bidens frondosa*
Leafy three-square	*Scirpus pungens*
Lemon beebalm	*Monarda citridora*
Lichens	

Live oak	*Quercus virginiana*
Lobelia	*Lobelia* sp.
Loblolly pine	*Pinus taeda*
Longleaf pine	*Pinus palustris*
Long-spined sandspur	*Cenchrus longispinus*
Loosestrifes	*Lythrium* spp.
Lovegrass	*Eragrostis* sp.
Lyngbye's sedge	*Carex lyngbeyii*
Mannagrass	*Glyceria striata*
Marestail	*Aster ericoides*
Marestail fleabane	*Erigeron canadensis*
Maritime pinweed	*Lechea maritima*
Marsh aster	*Aster paludosus*
Marsh dayflower	*Commelina communis*
Marsh boltonia	*Boltonia asteroides*
Marsh elder	*Iva frutescens*
Marsh fleabane	*Pluchea* sp.
Marsh goldenrod	*Solidago uliginosa*
Marsh loosestrife	*Lythrum lineare*
Marsh marigold	*Caltha asarifolia*
Marsh pepper	*Polygonum hydropiper*
Marsh rose mallow	*Hibiscus moscheutos*
Mallow yellowcress	*Rorippa islandica*
Mild water pepper	*Polygonum hydropiperoides*
Milkweed	*Ascepias incarnata*
Mimosa	*Albizzia julibrissin*
Mints	*Mentha* spp.
Mistletoe	*Phorandendron serotinum*
Mock bishop's weed	*Ptillimnium capillaceum*
Morning glory	*Ipomoea* sp.
Mosses	
Mouse-ear chickweed	*Cerastium vulgatum*
Mudwort	*Limosella aquatica*
Mulberry	*Morus* spp.
Najas	*Naias* spp.
Narrowleaf cattail	*Typha angustifolia*
Native red clover	*Trifolium pratense*
New Zealand spinach	*Tetragonia expansa*
Nightshade	*Solanum sisymbriifolium*
Nodding beggarticks	*Bidens cernua*
Nodding smartweed	*Polygonum lapathifolium*
Northern blackberry	*Rubus* sp.
Northern catalpa	*Catalpha* sp.
Northern dewberry	*Rubus flagellaris*
Northern red oak	*Quercus rubra*
Nutsedges	*Cyperus* spp.
Nuttall's oak	*Quercus nuttallii*
Nuttall's waterweed	*Elodea nuttallii*
Ogeechee plum	*Nyssa ogeche*
Onion	*Allium* sp.
Orach	*Atriplex semibaccata*
Orchard grass	*Dactylis glomerata*
Oregon bentgrass	*Agrostis oregonsis*

Overcut oak	*Quercus lyrata*
Pacific cordgrass	*Spartina foliosa*
Pacific glasswort	*Salicornia pacifica*
Pacific nine-bark	*Physocarpus capitatus*
Pacific silverweed	*Potentilla pacifica*
Palmetto	*Sabal louisiana*
Panic grasses	*Panicum* spp.
Parrot feather	*Myriophyllum* sp.
Peach	*Prunus persica*
Pearly everlasting	*Anaphalis margaritacea*
Pennywort	*Hydrocotyle* sp.
Pepperbush	*Clethra alnifolia*
Peppergrass	*Lepidium virginicum*
Peppervine	*Amepolopis arborea*
Perennial foxtail grass	*Setaria geniculata*
Perennial glasswort	*Salicornia virginica*
Perennial pea	*Lathyrus latifolius*
Perennial ryegrass	*Lolium perenne*
Perennial saltmarsh aster	*Aster tenuifolius*
Philadelphia daisy fleabane	*Erigeron philadelphicus*
Pickleweed	*Salicornia rubra*
Pickerelweed	*Pontederia cordata*
Pigeongrass foxtail	*Setaria glauca*
Pigweed	*Amaranthus* sp.
Pilewort	*Erechtites hieracifolia*
Plantain	*Plantago* sp.
Pointed rush	*Juncus oxymeris*
Poison ivy	*Rhus radicans*
Pokeweed	*Phytolacca americana*
Pondweeds	*Potomogeton* spp.
Poor-joe	*Diodia teres*
Prickly pear cactus	*Opuntia* sp.
Pumpkin ash	*Fraxinus tomentosa*
Purple loosestrife	*Lythrum salicaria*
Pussytoes	*Antennaria* sp.
Queen Anne's lace	*Daucus carota*
Quillwort	*Isoetes* sp.
Rabbits-foot clover	*Trifolium arvense*
Rabbitfoot grass	*Polypogon monspeliensis*
Ragwort	*Senecio* sp.
Raspberry	*Rubus* spp.
Rattail fescue	*Festuca myuros*
Rattlebean	*Sesbania* sp.
Red alder	*Alnus rubra*
Red fescue	*Festuca rubra*
Red maple	*Acer rubrum*
Red-osier dogwood	*Cornus stolonifera*
Red rattlebox	*Seabania punicea*
Red-rooted sedge	*Cyperus erythrorhizos*
Redtop	*Agrostis alba*
Reed canarygrass	*Phalaris arundinacea*
Rice cutgrass	*Leersia oryzoides*
River bulrush	*Scirpus fluvitialis*

River birch	*Betula nigra*
Roseate orach	*Atriplex rosea*
Rose mallow	*Hibiscus* sp.
Royal fern	*Osmunda regalis*
Rudbeckia	*Rudbeckia laciniata*
Rushes	*Juncus* spp.
Ryegrass	*Lolium perenne*
Sago pondweed	*Potomogeton pectinatus*
Saltbush	*Atriplex* sp.
Saltgrass	*Distichlis spicata*
Salt cedar	*Tamarix gallica*
Saltflat grass	*Monanthochloe littoralis*
Saltmarsh aster	*Aster maritima*
Saltmarsh bulrush	*Scirpus robustus*
Saltmarsh cattail	*Typha domingensis*
Saltmarsh fleabane	*Pluchea purpurascens*
Saltmarsh morning glory	*Ipomoea sagittata*
Saltmarsh sand spurry	*Spergularia marina*
Saltmeadow cordgrass	*Spartina patens*
Saltwort	*Batis maritima*
Sandbar willow	*Salix interior*
Sand bur	*Cenchrus tribuloides*
Sandgrass	*Triplasis purpurea*
Sand pine	*Pinus clausa*
Sandspur	*Cenchrus pauciflorus*
Sand spurry	*Spergularis platensis*
Sassafras	*Sassafras albidum*
Saw grass	*Cladium jamaicensis*
Scotch broom	*Cytisus scoparius*
Scouring rush	*Equisetum hyemale*
Sea blite	*Jaumea* sp.
Sea lavender	*Limonium carolinianum*
Sea oats	*Uniola paniculata*
Sea oxeye	*Borrichia frutescens*
Sea purslane	*Sesuvium portulacastrum*
Sea rocket	*Cakile fusiformis*
Seashore dropseed	*Sporobolus virginicus*
Seashore mallow	*Kosteletykya virginica*
Seaside arrowgrass	*Triglochin maritima*
Seaside goldenrod	*Solidago sempervirens*
Seaside heliotrope	*Heliotropium curassavicum*
Sea purslane	*Sesuvium maritimum*
Sea watch	*Angelica lucida*
Sedges	*Carex* spp.
Sensitive fern	*Onoclea sensibilis*
Sericea lespedeza	*Lespedeza sericea*
Sesbania	*Sesbania exaltata*
Sheep sorrel	*Rumex acetosella*
Shortleaf pine	*Pinus echinata*
Sicklepod	*Cassia obtusifolia*
Silverleaf cinquefoil	*Potentilla* sp.
Silver maple	*Acer saccharinum*
Sitka spruce	*Picea sitchensis*

Six-weeks fescue	*Festuca octoflora*
Skullcap	*Scutellaria* sp.
Skunk cabbage	*Symplocarpus foetidus*
Slash pine	*Pinus elliottii*
Sleepy catchfly	*Silene antirrhina*
Slender arrowhead	*Sagittaria teres*
Slender rush	*Juncus tenuis*
Slough grass	*Spartina pectinata*
Slough sedge	*Carex obnupta*
Small white morning glory	*Ipomoea lacunosa*
Smell melon	*Cucurbita pepo*
Smartweeds	*Polygonum* spp.
Smooth beggarticks	*Bidens laevis*
Smooth cordgrass	*Spartina alterniflora*
Smooth sumac	*Rhus glabra*
Sneezeweed	*Helenium autumnale*
Soft camphorweed	*Heterotheca pilosa*
Soft rush	*Juncus effusus*
Softstem bulrush	*Scirpus validus*
Southern cattail	*Typha* sp.
Southern dewberry	*Rubus trivialis*
Southern hackberry	*Celtus laevigata*
Southern magnolia	*Magnolia grandiflora*
Southern wild rice	*Zizaneopsis miliacea*
Sowthistle	*Sonchus arvensis*
Spiderwort	*Tradescentia virginiana*
Spikerushes	*Eleocharis* spp.
Spiny sandspur	*Cenchrus echinatus*
Sprangle top	*Leptachloa* spp.
Spring water starwort	*Callitriche verna*
Spurge	*Euphorbia dentata*
Staghorn sumac	*Rhus typhina*
Stream lupine	*Lupinus rivulus*
St. Augustine grass	*Stenotaphrum secundatum*
St. John's wort	*Hypericum* sp.
Suckling clover	*Trifolium dubium*
Swamp dock	*Rumex verticillatus*
Swamp dogwood	*Cornus amomum*
Swamp milkweed	*Asclepias incarnata*
Swamp rose	*Rosa palustris*
Sweet clover	*Melilotus officinalis*
Sweet gum	*Liquidambar styraciflua*
Switchgrass	*Panicum virgatum*
Tall fescue	*Festuca elatior*
Tall wheatgrass	*Agropyron elongatum*
Tansy	*Tanacetum vulgare*
Tapered rush	*Juncus acuminatus*
Thistle	*Cirsium* sp.
Thorny amaranth	*Amaranthus altissima*
Timothy	*Phleum pratense*
Torpedo grass	*Panicum repens*
Tree-of-heaven	*Ailanthus altissima*
Trailing wildbean	*Apios americana*

Trumpet creeper	*Caqmpsis radicans*
Tufted hairgrass	*Deschampsia caespitosa*
Tulip poplar	*Liriodendron tulipifera*
Vasey grass	*Paspaulm urvillei*
Vetches	*Vicia* spp.
Virginia creeper	*Parthenocissus quinquefolia*
Virginia glasswort	*Salicornia virginica*
Water buttercup	*Ranunculus septentrionalis*
Water celery	*Vallisneria spiralis*
Water cress	*Rorippa nasturtium-aquaticum*
Water foxtail	*Alopecurus geniculatus*
Water hemlock	*Cicuta maculata*
Water hemp	*Amaranthus cannabinis*
Water horehound	*Lycopus americanus*
Water hyssop	*Bacopa monnieri*
Water hyacinth	*Eichhornia crassipes*
Watermelon	*Citrullus vulgaris*
Water parsnip	*Sium sauve*
Water pennywort	*Hydrocotyle bonariensis*
Water plantain	*Alisma plantago-aquatica*
Water purslane	*Ludwigia palustris*
Water smartweed	*Polygonum punctatum*
Water willow	*Justicia americana*
Watson's willow-herb	*Epilobium watsonii*
Wax myrtle	*Myrica cerifera*
Western wheatgrass	*Agropyron smithii*
White ash	*Fraxinus americana*
White Dutch clover	*Trifolium repens*
White mulberry	*Morus alba*
White thoroughwort	*Eupatorium album*
White water lily	*Nymphaea odorata*
Widgeongrass	*Ruppia maritima*
Wild bean	*Strophostyles unbellata*
Wild carrot	*Daucus carota*
Wild lettuce	*Lactuca canadensis*
Wild morning glory	*Ipomoea* sp.
Wild oats	*Avena sativa*
Wild oatgrass	*Avena* sp.
Wild onion	*Allium canadense*
Wild peppergrass	*Lepidium* sp.
Wild rice	*Zizania aquatica*
Wild rye	*Elyus virginicus*
Willows	*Salix* spp.
Winged sumac	*Rhus copallina*
Winterfat	*Eurotia lanata*
Wisteria	*Wisteria* sp.
Woodbine	*Parthenocissus quinquefolia*
Wood nettle	*Laportea canadensis*
Woolly croton	*Croton capitata*
Yankee weed	
Yarrow	*Achillea millefolium*
Yaupon	*Ilex vomitoria*
Yellow flag	*Iris pseudacorus*

Yellow monkey flower	*Mimulus gullatas*
Yellow nutsedge	*Cyperus rotundus*
Yerba	*Eclipta alba*
Yucca	Yucca treculeana

Birds

Alder flycatcher	*Empidonax alnorum*
American avocet	*Recurvirostra americana*
American bittern	*Botaurus lentiginosus*
American black duck	*Anas rubripes*
American coot	*Fulica americana*
American crow	*Corvus brachyrhynchos*
American goldfinch	*Spinus tristis*
American kestrel	*Falco sparvesius*
American oystercatcher	*Haematopus palliatus*
American redstart	*Setophaga ruticilla*
American robin	*Turdus migratorius*
American tree sparrow	*Spizella arborea*
American white pelican	*Pelecanus erthrorynchos*
American widgeon	*Anas americana*
American woodcock	*Scolopax minor*
Baird's sandpiper	*Calidris bairdii*
Bald eagle	*Haliaeetus leucophalus*
Bank swallow	*Riparia riparia*
Barn swallow	*Hirundo rustica*
Barrow's goldeneye	*Bucephaia inslandica*
Belted kingfisher	*Megaceryle alcyon*
Bewick's wren	*Thryomanes bewickii*
Bitterns	*Ardeidae*
Black-and-white warbler	*Mniotilta varia*
Black-bellied plover	*Squatarola squaratola*
Black-capped chickadee	*Parus altricapillus*
Black-crowned night-heron	*Nycticorax nycticorax*
Black-headed grosbeak	*Pheucticus melanocephalus*
Black-necked stilt	*Himantopus mexicanus*
Blackpoll warbler	*Dendroica striata*
Black rail	*Laterallus jamaicensis*
Black-shouldered kite	*Elanus caeruleus*
Black skimmer	*Rynchops niger*
Black tern	*Chidonias niger*
Black-throated blue warbler	*Dendroica caerulescens*
Black-throated gray warbler	*Dendroica nigrescens*
Black turnstone	*Arenaria melanocephala*
Black vulture	*Coragyps atratus*
Blue-gray gnatcatcher	*Polioptila caerulea*
Blue grosbeak	*Guiraca caerulea*
Blue jay	*Cyanocitta cristata*
Blue-winged teal	*Anas discors*
Boat-tailed grackle	*Cassidix mexicanus*
Bobolink	*Dolichonyx oryzivorus*

Bohemian waxwing	*Bombycilla garrulus*
Boneparte's gull	*Larus philadelphia*
Brant's cormorant	*Phalacrocorax penicillatus*
Brewer's blackbird	*Euphagus cyanodephalus*
Broad-winged hawk	*Buteo platypterus*
Brown-headed cowbird	*Molothrus ater*
Brown pelican	*Pelecanus occidentalis*
Brown thrasher	*Toxostoma rufum*
Bufflehead	*Bucephala albeola*
California gull	*Larus californicus*
Canada goose	*Branta canadensis*
Canvasback	*Aythya valisineria*
Cape May warbler	*Dendroica tigrina*
Carolina chickadee	*Parus carolinensis*
Caspian tern	*Sterna caspia*
Cattle egret	*Bubulcus ibis*
Cedar waxwing	*Bombycilla cedrorum*
Chestnut-sided warbler	*Dendroica pennsylvanica*
Chimney swift	*Chaetura pelagica*
Chipping sparrow	*Spizella passerina*
Cinnamon teal	*Anas cyanoptera*
Clapper rail	*Rallus longirostris*
Cliff swallow	*Petrochelidon pyrrhonota*
Common gallinule	*Gallinula chloropus*
Common goldeneye	*Bucephala clangula*
Common grackle	*Quiscalus quiscala*
Common loon	*Gavia immer*
Common merganser	*Mergus merganser*
Common nighthawk	*Chordeiles minor*
Common snipe	*Gallinago gallinago*
Common raven	*Corvus corax*
Common tern	*Sterna hirundo*
Common yellowthroat	*Geothlypis trichas*
Dark-eyed junco	*Junco hyemalis*
Double-crested cormorant	*Phalacrocorax auritus*
Downy woodpecker	*Picoides pubescens*
Dunlin	*Erolia alpina*
Dusky flycatcher	*Empidonax oberholseri*
Eared grebe	*Podiceps nigricollis*
Eastern bluebird	*Sialia sialis*
Eastern kingbird	*Tyrannus tyrannus*
Eastern meadowlark	*Sturnella magna*
Eastern phoebe	*Sayornis phoebe*
Eastern wood-pewee	*Contopus virens*
European starling	*Sturnus vulgaris*
Field sparrow	*Spizella pusilla*
Fish crow	*Corvus ossifragus*
Forster's tern	*Sterna forsterii*
Fox sparrow	*Passerella iliaca*
Franklin's gull	*Larus pipixcan*
Gadwall	*Anas strepera*
Glaucous gull	*Larus hyperboreus*
Glaucous-winged gull	*Larus glaucescens*

Golden-crowned kinglet	*Regulus satrapa*
Gray catbird	*Dumtella carolinensis*
Great black-backed gull	*Larus marinus*
Great blue heron	*Ardea herodias*
Great crested flycatcher	*Myiachus crinitus*
Great egret	*Casmerodius albus*
Greater scaup	*Aythya marila*
Great horned owl	*Bubo virginianus*
Great-tailed grackle	*Quiscalus mexicanus*
Greater white-fronted goose	*Anser albifrons*
Greater yellowlegs	*Tringa melanoleuca*
Green-backed heron	*Butorides virescens*
Green-winged teal	*Anas crecca*
Gull-billed tern	*Sterna nilotica*
Gulls	*Larus* spp.
Hairy woodpecker	*Dendrocopos villosus*
Hermit thrush	*Catharus guttatus*
Herring gull	*Larus argentatus*
Hooded merganser	*Lophodytes cucullatus*
Hooded warbler	*Wilsonia citrina*
Horned grebe	*Podiceps auritus*
Horned lark	*Eremophila alpestris*
House sparrow	*Passer domesticus*
House wren	*Troglodytes aedon*
Hutton's vireo	*Vireo huttoni*
Indigo bunting	*Passerina cyanea*
Killdeer	*Charadrius vociferus*
King rail	*Rallus elegans*
Knot	*Calidris canutus*
Lark sparrow	*Chondestes grammacus*
Laughing gull	*Larus atricilla*
Least flycatcher	*Empidonax minimus*
Least sandpiper	*Erolia minutilla*
Least tern	*Sterna albifrons*
LeConte's sparrow	*Ammodramus leconteii*
Lesser scaup	*Aythya affinis*
Lesser yellowlegs	*Totanus falvipes*
Lewis' woodpecker	*Melanerpes lewis*
Little blue heron	*Florida coerulea*
Loggerhead shrike	*Lanius ludovicianus*
Long-billed curlew	*Numenius americanus*
Long-billed dowitcher	*Limnodromus scoplopercus*
Magnolia warbler	*Dendroica magnolia*
Mallard	*Anas platyrhynchos*
Marbled godwit	*Limosa fedoa*
Marsh wren	*Cistothorus palustris*
Merlin	*Falco columbarius*
Mew gull	*Larus canus*
Mottled duck	*Anas fulvigula*
Mourning dove	*Zenaida macroura*
Mute swan	*Cygnus olor*
Nashville warbler	*Vemrivora ruficapilla*
Northern bobwhite	*Colinus virginianus*

Northern cardinal	*Richmondena cardinalis*
Northern flicker	*Colaptes auratus*
Northern harrier	*Circus cyaneus*
Northern mockingbird	*Mimus polyglottos*
Northern oriole	*Icterus galbula*
Northern phalarope	*Lobipes labatus*
Northern pintail	*Anas acuta*
Northern rough-winged swallow	*Stelgidopteryx serripennis*
Northern shoveler	*Anas clypeata*
Northern waterthrush	*Seiurus noveboracensis*
Olivaceous cormorant	*Phalacrocorax olivaceus*
Orange-crowned warbler	*Vermivora celata*
Orchard oriole	*Icterus spurius*
Osprey	*Pandion haliaetus*
Ovenbird	*Seiurus aurocapillus*
Painted bunting	*Passerina ciris*
Palm warbler	*Dendroica palmarum*
Pectoral sandpiper	*Calidris melanotos*
Peregrine falcon	*Falco peregrinus*
Pied-billed grebe	*Podilymbus podiceps*
Pine warbler	*Dendroica pinus*
Piping plover	*Charadrius melodus*
Prairie warbler	*Dendroica discolor*
Prothonotary warbler	*Protonotaria citrea*
Purple finch	*Carpodacus purpureus*
Purple martin	*Progna subis*
Red-bellied woodpecker	*Centurus carolinus*
Red-breasted merganser	*Mergus serrator*
Red-breasted sapsucker	*Sphyrapicus ruber*
Reddish egret	*Egretta rufescens*
Red-eyed vireo	*Vireo olivaceus*
Redhead	*Aythya americana*
Red-headed woodpecker	*Melanerpes erthrocephalus*
Red knot	*Calidris canutus*
Red-tailed hawk	*Buteo jamaicensis*
Red-throated loon	*Gavis stellata*
Red-winged blackbird	*Agelauis phoeniceus*
Ring-billed gull	*Larus delawarensis*
Ring-necked duck	*Aythya collaris*
Ring-necked pheasant	*Phasianus colchicus*
Roseate spoonbill	*Ajaia ajaja*
Rose-breasted grosbeak	*Pheucticus ludovicianus*
Rough-legged hawk	*Buteo lagopus*
Royal tern	*Larus maximus*
Ruby-crowned kinglet	*Regulus calendula*
Ruby-throated hummingbird	*Archilochus colubris*
Ruddy duck	*Oxyura jamaicensis*
Ruddy turnstone	*Arenaria interpres*
Rufous hummingbird	*Selasphorus rufus*
Rufous-sided towhee	*Pipilo erythrophthalmus*
Rusty blackbird	*Euphagus carolinus*
Sabine's gull	*Xema sabini*
Saltmarsh song sparrow	*Melospiza melodia*

Sanderling	*Calidris alba*
Sandpipers	*Calidris* spp.
Sandwich tern	*Sterna sandvicensis*
Savannah sparrow	*Passerculus sandwichensis*
Scissor-tailed flycatcher	*Muscivora forficata*
Screech owl	*Otus asio*
Sea lion	*Zalophus californianus*
Seaside sparrow	*Ammospiza maritima*
Semipalmated plover	*Charadrius semipalmatus*
Semipalmated sandpiper	*Calidris pusilla*
Sharp-shinned hawk	*Accipiter striatus*
Sharp-tailed sparrow	*Ammodramus caudacutus*
Short-billed dowitcher	*Limnodromus griseus*
Short-eared owl	*Asio flammeus*
Snow bunting	*Plectrophenax nivalis*
Snow goose	*Chen caerulescens*
Snowy egret	*Leucophoyx thula*
Snowy plover	*Charadrius alexandrinus*
Solitary sandpiper	*Tringa solitaria*
Song sparrow	*Melospiza melodia*
Sooty tern	*Sterna fuscata*
Sora	*Porzana carolina*
Spotted sandpiper	*Actitis macularis*
Stilt sandpiper	*Calidris himantopus*
Swainson's thrush	*Catharus ustulatus*
Swallows	*Hirundo* spp.
Swamp sparrow	*Melospiza georgiana*
Tennessee warbler	*Vermivora peregrina*
Terns	*Sterna* spp.
Townsend's warbler	*Dendroica townsendi*
Tree swallow	*Iridoprocne bicolor*
Tri-color heron	*Hydranassa tricolor*
Tundra swan	*Cygnus columbianus*
Upland sandpiper	*Bartramia longicauda*
Vaux's swift	*Chaetura vauxi*
Veery	*Catharus fuscescens*
Vesper sparrow	*Pooecetes gramineus*
Violet-green swallow	*Tachycineta thalassina*
Virginia rail	*Rallus limicola*
Warbling vireo	*Vireo gilvus*
Water pipit	*Anthus spinoletta*
Western bluebird	*Sialia mexicana*
Western flycatcher	*Empidonax difficilis*
Western gull	*Larus occidentalis*
Western kingbird	*Tyrannus verticalis*
Western meadowlark	*Sturnella neglecta*
Western sandpiper	*Ereunetes mauri*
Western wood-pewee	*Contopus sordidulus*
Whimbrel	*Numerius phaeopus*
White-crowned sparrow	*Zonotrichia laucophrys*
White-eyed vireo	*Vireo griseus*
White-faced ibis	*Plegadis chihi*
White ibis	*Eudocimus albus*

White-rumped sandpiper	*Calidris minutilla*
White-throated sparrow	*Zonotrichia albicollis*
Willet	*Catophrophorus semipalmatus*
Willow flycatcher	*Empidonax traillii*
Wilson's plover	*Characrius wilsonia*
Wilson's warbler	*Wilsonia pusilla*
Winter wren	*Troglodytes troglodytes*
Wood duck	*Aix sponsa*
Wood thrush	*Hylocichla mustelina*
Worm-eating warbler	*Helmitheros vermivorus*
Yellow-bellied sapsucker	*Sphyrapicus varius*
Yellow-breasted chat	*Icteria virens*
Yellow-billed cuckoo	*Coccyzus americanus*
Yellow-crowned night-heron	*Nyctanassa violacea*
Yellow rail	*Coturnicops noveboracensis*
Yellow-rumped warbler	*Dendroica coronata*
Yellow-throated warbler	*Dendroica dominica*
Yellow warbler	*Dendroica petechia*

Fish and Other Aquatic Biota

Alewife	*Alosa pseudoharengus*
American shad	*Alosa americanus*
Amphipods	Amphipoda
Anchovies	*Anchoa* spp.
Asiatic clam	*Corbicula fluminea*
Atlantic bumper	*Chloroscombrus chrysurus*
Atlantic croaker	*Micropogon undulatus*
Atlantic herring	*Clupea harengus*
Atlantic menhaden	*Brevoortia tyrannus*
Atlantic silversides	*Menidia menidia*
Atlantic thread herring	*Opisthonema oglinum*
Barnacle larvae	*Lepas* sp.
Bay anchovy	*Anchoa* sp.
Blueback herring	*Alosa aestivalis*
Blue crab	*Callinectes sapidus*
Blue gill	*Lepomis pallidus*
	Branchiura sowerbyi
Brown shrimp	*Penaeus aztecus*
Bullhead	*Amciurus nebulosus*
Carp	*Cyprinus carpio*
Catfish	*Ictalurus punctatus*
	Capitella capitata
Channel catfish	*Ictalurus catus*
Chinook salmon	*Onchorhynchus tshaivytscha*
Chironomid larvae	Chironomidae
	Coelotanypus spp.
Coho salmon	*Onchorhynchus kisutch*
Common anchovy	*Anchoa mitchilli*
Copepods	Copepoda
	Corbicula flumenia

	Corophium spp.
	Corophium salmonis
Crappie	*Pomixis* spp.
	Enchytraeidae
	Eteone heteropoda
Fiddler crabs	*Uca* spp.
Flddler crab	*Uca pugnax*
Fingernail clams	
Flounder	*Paralichthys albigutta*
Freshwater goby	*Gobionellus shufeldti*
Gastropods	Gastropoda
	Glycinde solitaria
Grass shrimp	*Panaemonetes pugio*
Gulf menhaden	*Brevoortia patromus*
	Hargaria rapox
Haustorid amphipods	Amphipoda
Hermit crabs	Paguroidae
	Heteromastus filiformis
Hogchoker	*Trinectes maculatus*
	Hyallela azteca
Isopods	Isopoda
Killifish	*Fundulus* spp.
	Laeoneris culveri
Largemouth bass	*Micropeterus salmoides*
	Limnodrilus spp.
	Limnodrilus hoffmeisteri
	Loandalia fauveli
	Lumbriculidae
Lymniad snails	Lymnidae
	Macoma constricta
Marine worms	*Diopatra* spp.
	Mediomastus spp.
Menhaden	*Brevoortia tyrannus*
Mullet	*Mugil* spp.
Mummichog	*Fundulus heteroclitus*
	Nereis succinea
Northern pike	*Esox lucius*
Oligochaetes	Oligochaeta
Oyster	*Crassostea virginica*
Pacific lamprey	*Entosphenus tridentatus*
	Paleomonetes spp.
Peamouth	*Mylocheilus caurinus*
	Peloscolex freyi
	Peloscolex multisetosus
Perch	*Morone* spp.
Periwinkle	
	Polydora ligni
	Pontoporeis affinis
Polychaetes	Polychaeta
	Procladius spp.
Redfish	*Sebastes marinus*
Salmon	*Oncorhynchus* spp.
Seatrout	*Cynoscion nebulosus*

Sheepshead	*Archosargus probatocephalus*
Smelt	Osmeridae
Sockeye salmon	*Onchorhynchus nerka*
Sphaerid clams	Sphaeridae
Spot	*Leiostomus xanthurus*
Squid	*Loligo brevirostrum*
Stardrum	*Stellifer lanceolatus*
Starry flounder	*Platichthys stellatus*
	Streblospio benecicti
Striped bass	*Morone saxatilis*
Striped mullet	*Mugil cephalus*
Sturgeon	*Acipenser* sp.
Sunfishes	*Lepomis* spp.
Tenanthurid isopods	Isopoda
Threespine stickleback	*Gasterosteus aculeatus*
Trout	*Salmo* spp.
Tubificid worms	Tubificidae
Weakfish	*Cynoscion regalis*
White catfish	*Ictalurus catus*
White mullet	*Mugil curema*
White perch	*Morone americanus*
White shrimp	*Penaeus setiferus*
Whiting	*Urophycis* spp.

Mammals and Other Terrestrial Biota

American alligator	*Alligator mississipiensis*
Ants	Formicidae
Banded watersnake	*Natrix fasciata pictiventris*
Beaver	*Myrocastor canadensis*
Beetles	Cicindelidae
Black racer	*Coluber constrictor*
Brine flies	Ephydridae
Caddisflies	Trichoptera
Columbia white-tailed deer	*Odecoileus virginiana columbiana*
Cotton rat	*Sigmadon hispidus*
Deer mouse	*Peromyscus maniculatus*
Diamondback terrapin	*Malaclemys terrapin centrata*
Dog	*Canis familiaris*
Eastern cottontail	*Sylvilagus virginiana*
Eastern mole	*Scalopus aquaticus*
Fire ants	*Solenopsis saevissima richteri*
Goat	*Capra hircus*
Gopher tortoise	*Gopherus polyphemus*
Grasshopper	Locustinae
Harbor seal	*Phoca vitulina*
Hispid cotton rat	*Sigmodon hispidus*
Horned toad	*Phrynosoma cornutum*
House mouse	*Mus musculus*
Land snails	
Leech	Piscicolidae

Marsh rice rat	*Oryzomys palustris*
Mayflies	Ephemeroptera
Meadow jumping mouse	*Zapus hudsonius*
Meadow vole	*Microtus pennsylvanicus*
Muskrat	*Ondatra zibethicus*
Nine-banded armadillo	*Dasypus novemcinctus*
Norway rat	*Rattus norvegicus*
Nutria	*Myocastor coypus*
Opossum	*Didelphis marsupialis*
Raccoon	*Procyon lotor*
Red fox	*Vulpes fulva*
River otter	*Lutra canadensis*
Sea lion	*Zalophus californianus*
Short-tailed shrew	*Blarina brevicauda*
Shrews	*Blarina* spp.
Skunks	*Mephitis mephitis*
Snails	
Spider mite	Acarina
Swamp rabbit	*Sylvilagus aquaticus*
Tiger beetles	Cicindalidae
Townsend's vole	*Microtus townsendii*
Trowbridge's shrew	*Sorex trowbridgii*
Vagrant shrew	*Sorex vagrans*
Voles	Cricetidae
White-footed mouse	*Peromyscus erthrorynchos*
Woodchuck	*Marmota monax*